The Fisheries and Limnology of Oneida Lake 2000-2009

New York Federal Aid in Sport Fish Restoration
Study 1
F-56-R

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Introduction

Oneida Lake is the largest lake by area within the borders of New York State. The recent 2007 New York Statewide Angler Survey revealed that Oneida Lake is second only to Lake Ontario in the amount of angling it attracts, with some 786,000 angler days of effort reported for the year 2007 (Connelly and Brown 2009). Angling on Oneida Lake generates revenues of over 12 million dollars annually, and as such represents an important resource both locally and state wide (Connelly and Brown 2009). Traditionally, walleye *Sander vitreus* has been the centerpiece of the Oneida Lake fishery, with yellow perch *Perca flavescens* and black bass (smallmouth bass *Micropterus dolomieu* and largemouth bass *M. salmoides*) also providing popular fisheries. Both the 2007 Statewide Survey and site-specific creel surveys conducted from 2002-2007 found that walleye continue to be the most frequently targeted sport fish in Oneida Lake, representing 57.5% of the effort captured by the Statewide Survey and 67.7% of effort during 6 years of on-lake interviews (Connelly and Brown 2009; Krueger et al. 2009). While yellow perch remain popular (10.4% targeted effort in the Statewide Survey, 14.3% in the Oneida Creel Survey), black bass have increased in popularity in recent years and now rank as the second most pursued fishery on the lake. The Statewide Survey found that 21.7% of anglers visiting Oneida Lake sought bass, while the on-site survey found that 15.6% of effort was directed at bass. The bass fishery appears to be growing in popularity in recent years, and much of the growth appears related to tournament fishing, with some 67 tournaments scheduled on the lake in 2010 season (see http://www.hanktimmermann.com/pages/sheet.xls).

The walleye population has been intensively managed on Oneida Lake, including annual stockings of 150 million walleye fry, almost complete removal of double-crested cormorants *Phalacrocorax auritus* from the lake for the past 6 years, and angling regulations that have been imposed and relaxed with the goals of retaining both a high walleye yield and a yellow perch population capable of providing forage for walleye and larger fish attractive to anglers (Forney 1980). Angling regulations are based on intensive monitoring of the walleye and yellow perch populations and predicted walleye recruitment. Oneida Lake has been the subject of research by the Cornell Biological Field Station (CBFS) since its establishment in 1956. Work on Oneida Lake is an important part of the collaboration between Cornell's Department of Natural Resources and New York State Department of Environmental Conservation's Bureau of Fisheries (NYSDEC), and results of research not only inform management of this important fishery but also provide insights into ecological relationships in other New York waters. Research and monitoring on Oneida Lake is designed to encompass a range of trophic levels, from nutrients to fish and anglers, and these data are used to improve our understanding of the interactions between the ecosystem and the fishery in Oneida Lake.

During the time span that data have been collected on Oneida Lake, several perturbations have resulted in fundamental changes in the lake and how it functions. This report provides a summary of the standard monitoring data for 2009, along with an appendix with standardized methods for data collection and standard data tables. In our report of 2008 results, we presented results of analyses of long-term trends in the lake and interpreted them in light of observed perturbations (Rudstam et al. 2009). While the occurrence of shifts in conditions over the long-term is unquestionable, we have yet to address the question of whether the lake is in a continuing state of change, or might have reset with new norms for productivity and fish production. Here, we present analyses of trends in lake biology over the past decade (2000-2009) to assess whether the lake has reset to a new state or continues to demonstrate changing trends in physical and biological features.

Several of the data sets are also available on the web at the Cornell University Mann Library's site eCommons (http://ecommons.library.cornell.edu/) and through the Knowledge Network for Biocomplexity (http://knb.ecoinformatics.org/index.jsp) (Rudstam and Mills 2008a-e, Rudstam and Jackson 2008a, b).

Collection of data to maintain the long-term database and directed studies aimed at understanding the effects of ecosystem change on the fish populations were continued in 2009 by the Department of Natural Resources of Cornell University as part of the activities of CBFS. Funding was provided by NYSDEC through the Federal Aid in Sport Fish Restoration Program and from the CBFS endowment. Cormorant management and studies are supported by a grant from the USDA Animal and Plant Health Inspection Services National Wildlife Research Center (APHIS-NWRC).

Oneida Lake in 2009

Limnology

As in many recent years, ice cover formed, broke up and reformed before stable cover became established during the winter of 2008-2009. Ice cover first formed on Oneida Lake on 20 December 2008 and broke up 25 December. Ice reformed on 1 January 2009 and remained until ice break up on 30 March 2009. Total ice duration for the winter of 2008-2009 was 83 days, 10 days shorter than the average ice duration for 1975-2008 (Appendix Table A1). Ice duration has shown a significant decreasing trend over the period for which data have been collected (1975-2009), but no significant trend has been exhibited in the last decade (Table 1).

June-August water temperatures at 2 m depth during 2009 averaged 21.7 ^{o}C (71.1 ^{o}F), virtually identical to the long-term average (Appendix Table A1). Summer water temperatures in Oneida Lake have increased significantly over the full duration of record (1968-2009), but have not shown a significant trend over the past decade (Table 1).

While recent trends in ice duration and summer water temperatures do not exhibit the same significance as observed over the long term, both measurements of the lake's physical conditions reflect warmer conditions than when data collection first started. The average ice duration for the period 2000-2009 was 89.9 days, even excluding the winter of 2001 when secure ice never formed. Average ice duration from 1975-1984 was 102.5 days. The average June-August water temperatures during the last decade were 1.2 ^{o}C higher than for the decade of 1975-1984 (Figure 1).

Water clarity in 2009 was the third highest seen in the last decade, with a mean annual Secchi depth of 3.8 m and mean chlorophyll-*a* concentration of 4.1 µg/L (Figure 2, Appendix Table A1). This continues the period of high water clarity and low chlorophyll-*a* concentration that has characterized the lake since 1992, the year when zebra mussels (*Dreissena polymorpha*) became abundant in Oneida Lake (Zhu et al. 2006). Soluble reactive phosphorus (SRP) concentration was lower than any year since 2000, and comparable to the 1990-1999 period, when the lowest concentrations were recorded (Figure 2). Although there is a significant decreasing trend in SRP and chlorophyll-*a* concentration for the entire time series, there are no detectable trends during the last decade (Table 1). Following water quality improvement efforts and establishment of zebra mussels, the lake appears to have stabilized at levels that are typical of a mesotrophic lake (Wetzel 2001; Idrisi et al. 2001; Zhu et al. 2006).

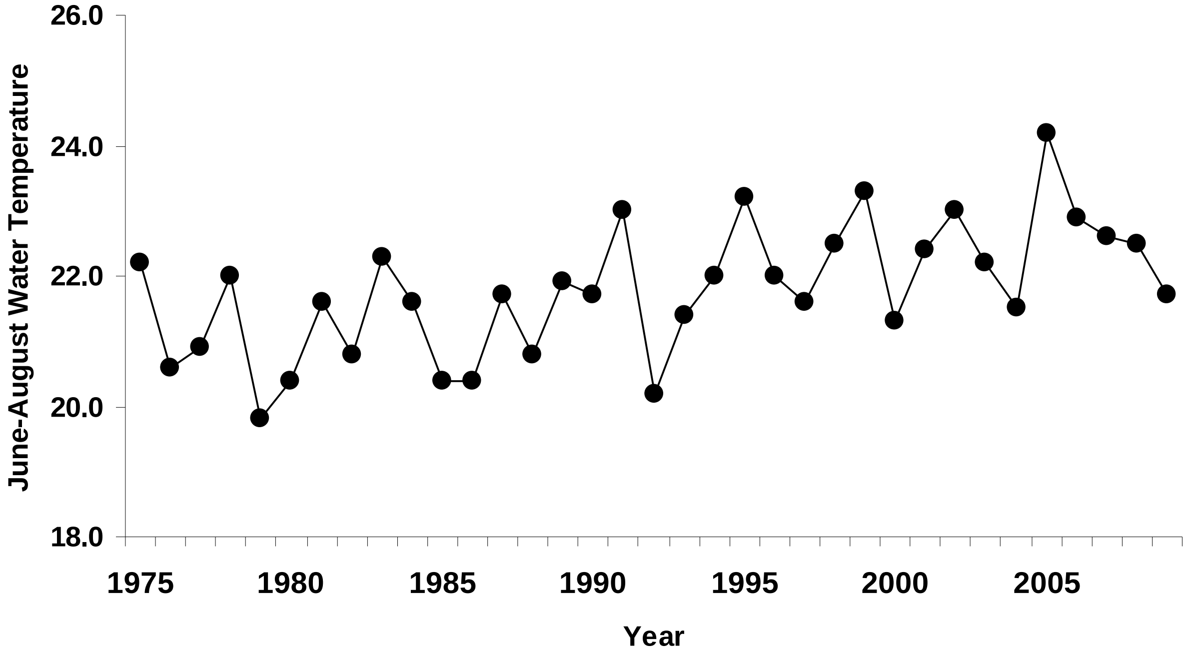

Figure 1. Average daily water temperature at 2 m depth at the Shackelton Point station from June 1 to August 31, Oneida Lake, New York, 1975-2009.

Total zooplankton and *Daphnia* biomass in 2009 were low relative to long-term measures (Figure 3). Total zooplankton biomass was the lowest observed since 1975, when data were first collected, and *Daphnia* biomass was lower than any year since 1978. While analyses of long-term trends in zooplankton indicated significant increases in both total zooplankton and *Daphnia* biomass, analyses of recent years indicate significant declines over the last decade (Table 1). These trends are consistent with initial expectations following establishment of zebra mussels and declines in phytoplankton biomass (as indexed by chlorophyll-*a*), although increases in planktivorous fishes could also come into play. Interestingly, declines in total zooplankton appear to be largely accounted for by declines in *Daphnia*. Whereas Daphnia have typically accounted for 55-65% of total zooplankton biomass, in recent years their contribution has fallen below 50% (Figure 4). While further study is needed, initial indications are that declines in *Daphnia* production are taking place largely with reduced early spring blooms. These blooms are frequently driven by diatoms, which appear to be declining in density in spring, as indicated by increased concentrations of silica, which is normally depleted by diatoms during the bloom stage (Figure 5, simple linear regression $r^2 = 0.49$, $P = 0.05$). These observed reductions in zooplankton production are of concern, as zooplankton are a critical food for supporting growth of early life stages of fish. We will continue to monitor zooplankton levels and look for changes in growth rates of planktivorous fishes.

Our analyses of long-term trends in physical and limnological features in Oneida Lake suggest that the lake has, in fact, transitioned into a new state of productivity since limnological studies were initiated in the 1970s. Reduced nutrient loading, combined with grazing by the introduced zebra mussel, had resulted in lower nutrient levels and reduced chlorophyll-*a* concentrations. We will need to monitor whether the expansion of the quagga mussel in Oneida Lake will further increase grazing rates and reduce algal concentrations. While Oneida Lake was once classified as a eutrophic lake, it now possesses characteristics of a mesotrophic lake. The absence of recent trends in nutrients and chlorophyll-*a* suggest that the lake has stabilized at a lower productivity level. While zooplankton biomass did not initially decrease as a result of decreased productivity, recent trends suggest that zooplankton biomass, particularly *Daphnia*, has declined from historic levels, and this may have implications for production of fish. Additionally, the discovery of *Hemimysis anomala* in the lake in 2009 will require careful monitoring, as this exotic shrimp may exert additional grazing pressure on zooplankton (Brooking et al. 2010). Water temperatures continue to be above average and ice duration below average for the data series. Combined with increases in water clarity, we expect the area of lake bottom covered by submerged macrophytes to increase in the future. These changes could result in shifts in the fish community and the limnology of the lake will require continued monitoring.

Table 1. Comparison of long-term (1975-2009) and recent trends (2000-2009) in physical and limnological measurements in Oneida Lake. Significance levels are based on simple linear regression using JMP 7.11. Limnological variables are averages of weekly whole water column samples from May through October (summer temperature is June-August, Appendix Table A1). Trend indicates direction (+ or -) over time, with r^2 and *P* reported for regressions.

	Long-Term 1975-2009			Last Decade 2000-2009		
Variable	Trend	r^2	*P*	Trend	r^2	*P*
Ice Duration (days)	**-**	0.17	**0.018**	-	0.08	0.45
Temperature Jun-Aug (ºC)	**+**	0.36	**0.0002**	+	0.02	0.67
Soluble Reactive Phosphorus (µg/L)	-	0.14	**0.03**	NT	0.00	0.90
Chlorophyll-*a* (µg/L)	-	0.47	**<0.001**	-	0.12	0.36
Secchi disk depth (m)	+	0.43	**<0.0001**	+	0.28	**0.11**
Daphnia biomass(µg/L)	+	0.06	0.17	-	0.52	**0.02**
Total zooplankton (µg/L)	+	0.14	**0.04**	-	0.29	**0.10**

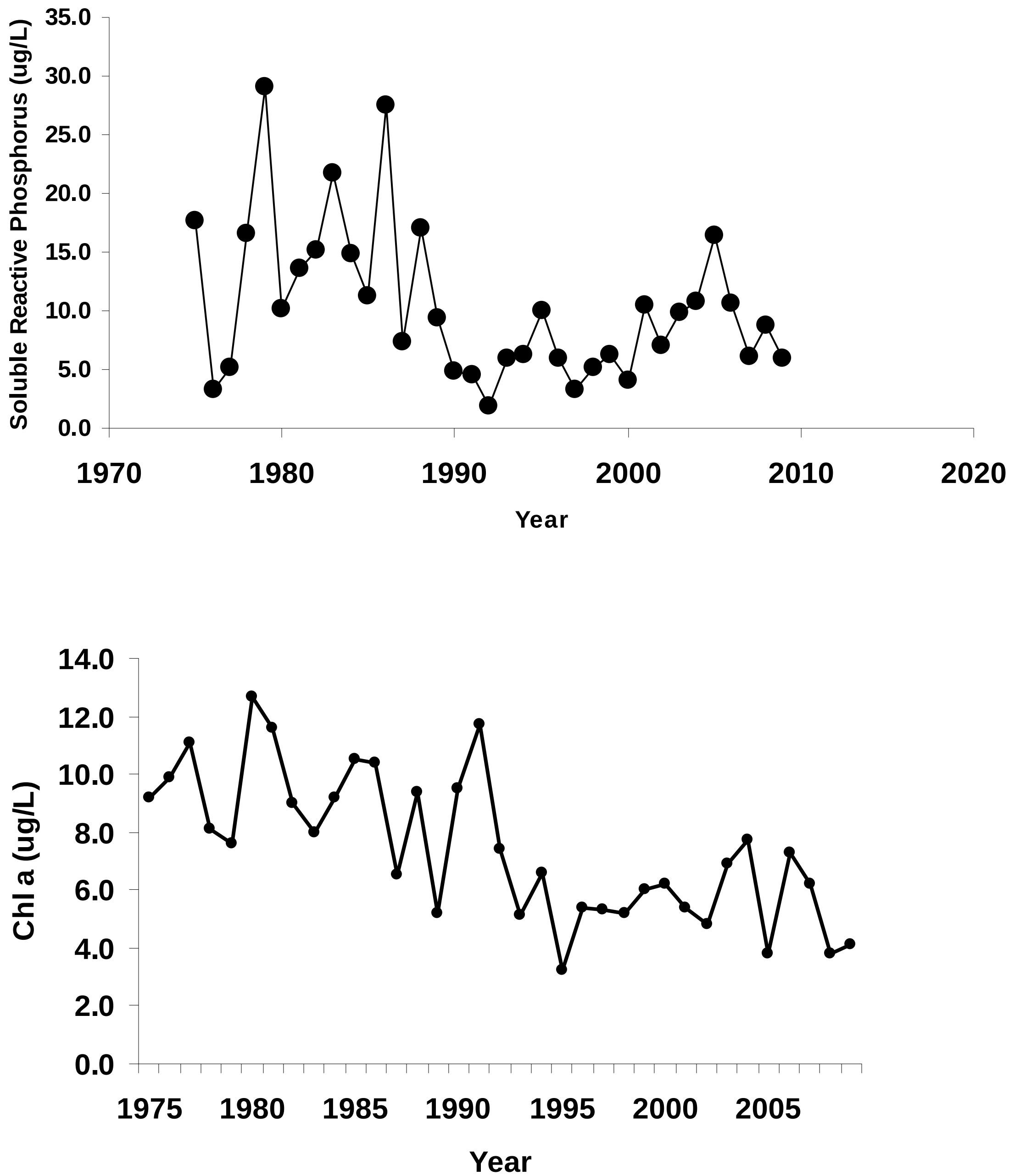

Figure 2. Time trends in lower trophic indicators in Oneida Lake, New York, 1975 to 2009.

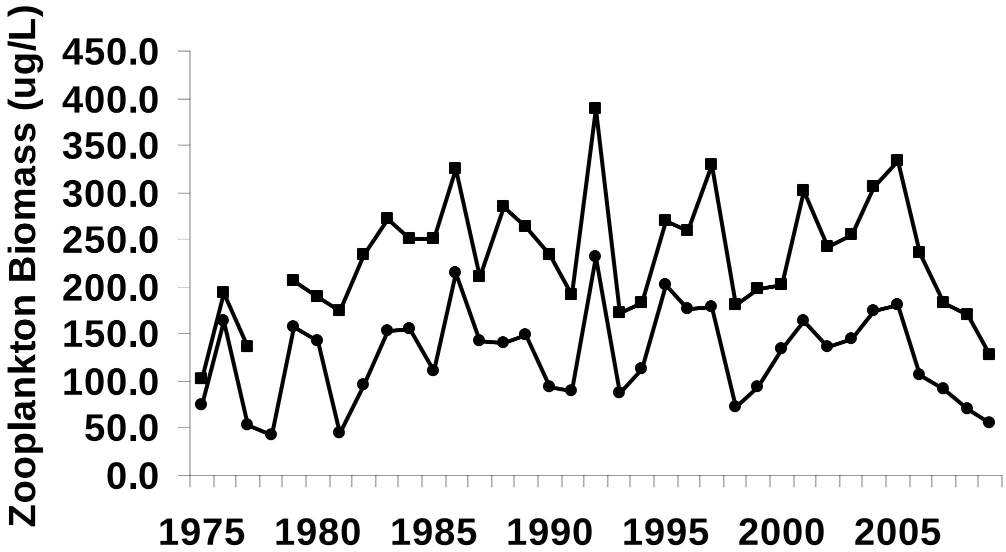

Figure 3. Time trends in total zooplankton biomass (upper line, with squares) and Daphnia biomass (lower line, with circles) in Oneida Lake, New York, 1975 to 2009.

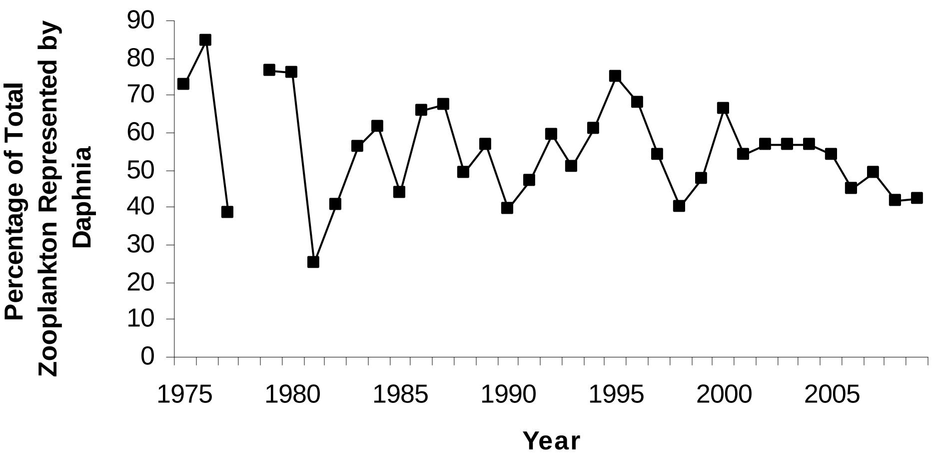

Figure 4. Time trend in percentage of total zooplankton biomass represented by Daphnia in Oneida Lake, New York, 1975-2009.

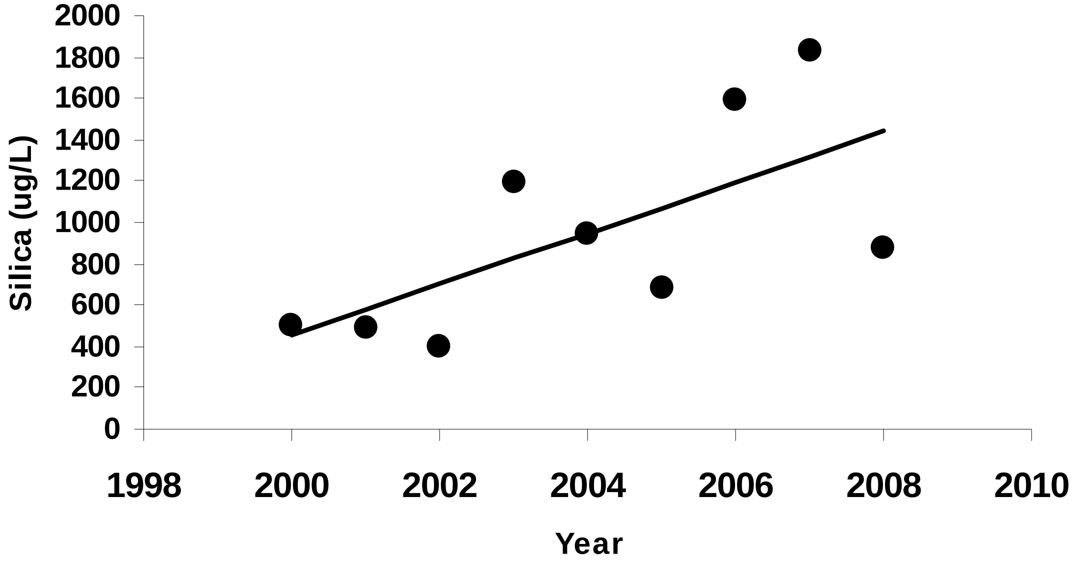

Figure 5. Time trend in silica concentration in Oneida Lake, New York, 2000-2009.

Fish Community Changes

Consistent with past years, gill net catches indicate that Oneida Lake continues to be dominated by yellow perch, white perch *Morone americana* and walleye. For only the second year on record, catches of white perch in gill nets exceeded those of yellow perch, with white perch representing 44% of the catch and yellow perch 32% (Figure 6). White perch was also the most abundant species in the catch in 2007 (46%). Walleye remained the third most abundant species in our gill net samples at 14 % of the catch. Total number of fish caught in the standard gill nets in 2009 was 1690, similar to the numbers caught throughout the 2000's.

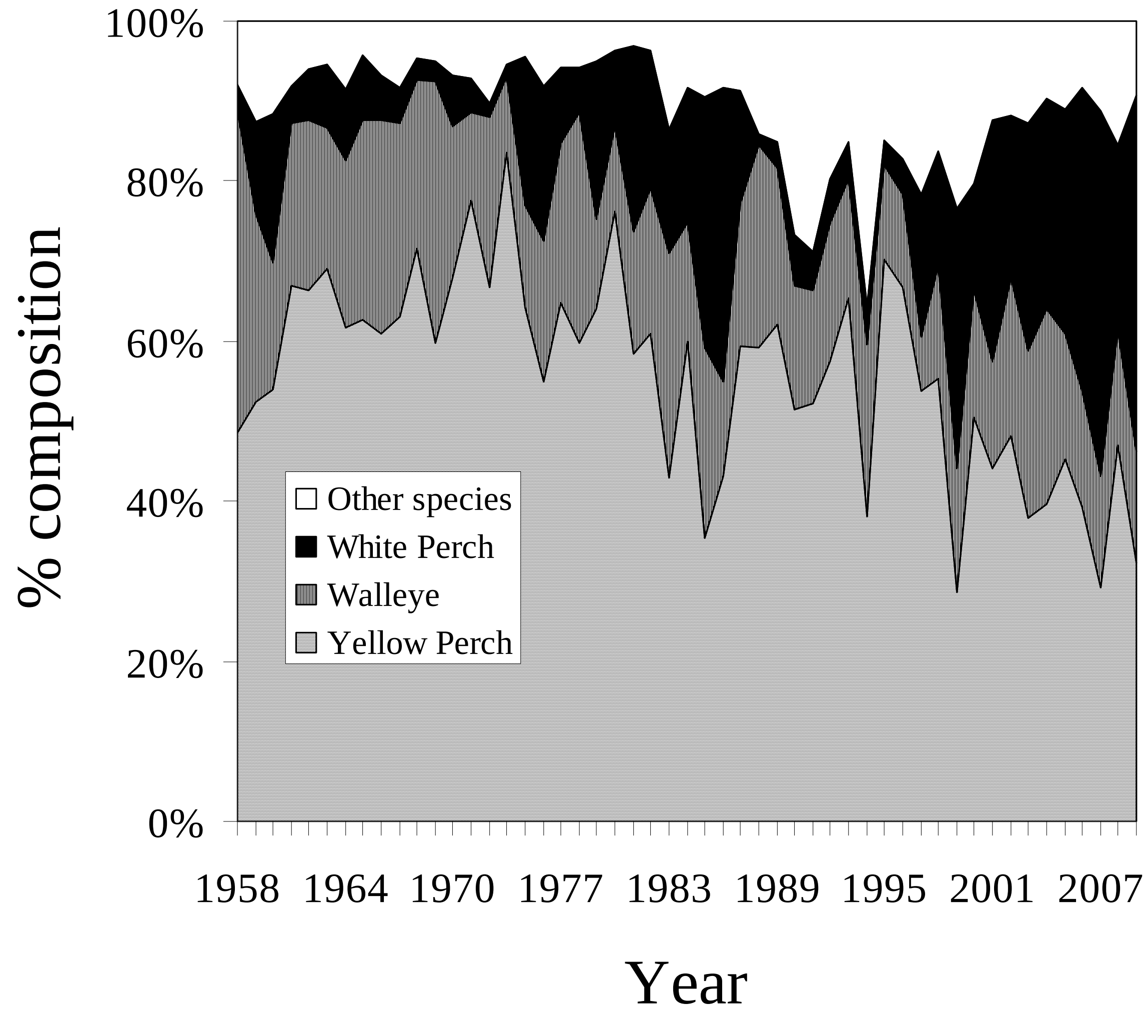

Figure 6. Proportion of three major fish species in standard gill net sets in Oneida Lake, New York, 1957-2009.

Walleye

We assess the walleye population in Oneida Lake at several stages; with Miller high speed samplers as larvae (lengths of 9 to 13 mm), with bottom trawls in the spring, summer and fall, with gill nets in the summer, and with mark-recapture for adult fish (age 4 and older) at regular intervals (currently every 3 years).

Abundance of adult walleye (age 4 and older) was estimated by mark-recapture in 2007 to be 18.7 fish/ha or 386,500 fish in the lake. The estimate for 2009, based on the 2007 mark-recapture estimate and assuming 15% annual mortality was 17.82 fish/ha, or a total population of 368,300 (Appendix Table A2). The decline in the adult population results primarily from generally poor recruitment in recent years, particularly from the 2002, 2003 and 2005 year classes. Over the full span of our data series, the adult walleye population has exhibited a significant decrease, but has shown a significant increase in the last decade, partly driven by a large 2001 year class and three years with more restrictive harvest regulations combined with cormorant management (Table 2).

Table 2. Comparison of long-term (1975-2009) and recent trends (2000-2009) in measurements of walleye abundance in Oneida Lake. Significance levels are based on simple linear regression using JMP 7.11. Data are presented in Appendix Tables A2 and A4.

	Long-Term 1975-2009			Last Decade 2000-2009		
Variable	Trend	r^2	*P*	Trend	r^2	*P*
Adult (age 4+) population size	-	0.29	**<0.0001**	+	0.56	**0.01**
Adult growth rate (male)	-	0.13	**0.01**	+	0.17	0.26
Adult growth rate (female)	-	0.09	**0.03**	+	0.23	0.19
Larval density	+	0.06	**0.13**	+	0.04	0.60
October 1 age-0 density	-	0.35	**<0.0001**	-	0.10	0.38
Spring age-1 density	-	0.23	**0.0006**	-	0.23	**0.03**

We predict future walleye recruitment using the average of catches in trawls and gill nets of age-1 and age-2 walleye (Appendix Table A2). We now estimate density of age 1 to 3 walleye from the average of the estimate from the trawl and the gill net using the age and gear specific catchabilities derived by Irwin et al. (2008) (see Appendix Table A2). Irwin et al. (2008) also showed that including a variable for cormorant foraging pressure improves predictions. The "best" model (lowest AIC) given the data for year classes 1957- 2004 includes the natural logarithm of age 1 and age 2 walleye abundance and an index of cormorant feeding days:

$$\mathrm{Ln(Age\ 4)} = -0.059 + 0.239\ \mathrm{Ln(Age\ 1)} + 0.593\ \mathrm{Ln(Age\ 2)} - 1.177\ \mathrm{DCCO} \qquad (1)$$

Where Age 1, Age 2 and Age 4 are densities of walleye age classes in fish/ha, and DCCO is the index of cormorant feeding days from Coleman (2009, updated by DeBruyne in prep.) ($r^2 = 0.84$, N = 48, $P<0.0001$ for the full model).

Our prediction for recruitment to age 4 of walleye produced by the 2006 year class in 2010 is 57,600 fish. Recruitment to age 4 of walleye produced by the 2007 year class in 2011 is predicted to be 90,400 fish. We continue to experience relatively low levels of recruitment as compared to the decades of the 1960s, 70s and 80s, particularly in the absence of occasional large year classes. Whether these recruitment levels are sufficient to maintain the walleye population at current levels depends on adult mortality rates, specifically annual harvest rates. Our harvest estimates for 2004-08, when current regulations were in effect, ranged from 31,000 to 58,000 fish annually (Krueger et al. 2009), with the most recent years of the survey producing harvest estimates very near the recruitment levels seen in recent year classes. Combined with natural mortality, these harvest rates may be sustainable, but the population is not likely to increase. Assuming a 15% total mortality in the future (average of observed mortality between mark-recapture estimates since 1995 (range 9 – 26%), we would expect the walleye population to remain at levels between 350,000 and 450,000 in the absence of an increase in recruitment rates or a decrease in harvest, consistent with recent numbers (Figure 7). We do not expect higher recruitment in the near future based on available data for the 2007, 2008 and 2009 year classes. For both 2007 and 2008, the densities at age 1 were below values for the 2005 and 2006 year-classes, and 2009 age-0 catches among the lowest on record. Therefore it is reasonable to expect the population will decrease in 2011-2013.

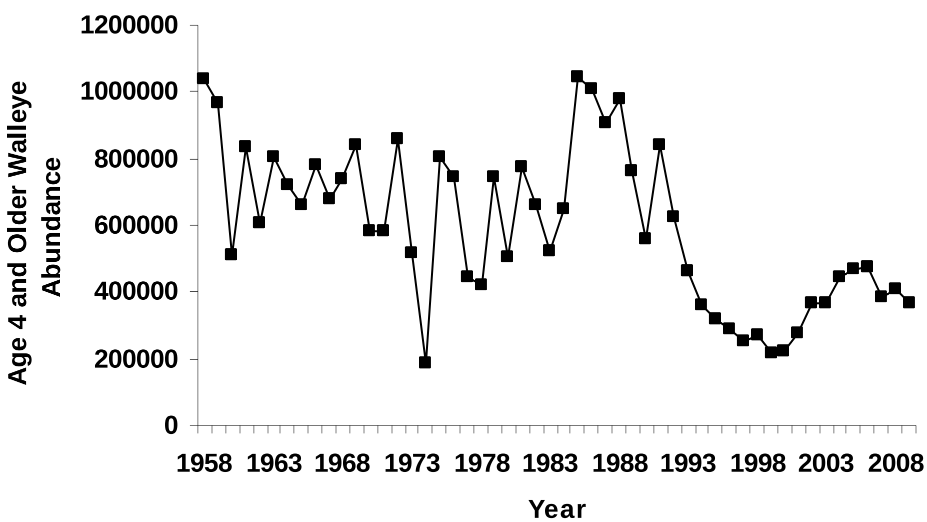

Figure 7. Abundance of walleye in Oneida Lake, New York, 1957-2009.

Adult walleye growth rate is calculated from back-calculated length-at-age of fish caught in the standard gill net sets. We use the geometric mean of growth in length from age 4 to 5, 5 to 6, and 6 to 7 as an index of growth rate. This index requires length at last annulus and therefore the data collected in 2009 represent growth in 2008 (we calculate growth for 2008 based on spring length in 2009). This index showed relatively low growth of adult walleye in recent years, but 2008 growth showed improvement (Figure 8). We did shift from use of scales to otoliths for aging and back calculations in 2009, and this may have contributed to the large changes in estimated growth rates observed when 2009 data were added to our time series. Walleye growth has historically been dependent on availability of yellow perch, with gizzard shad and white perch presumably providing additional forage. Relatively poor growth in the last decade indicates that walleye in Oneida Lake are abundant relative to the abundance of forage fish, and continued exploration of the predator-prey dynamics in the lake are necessary in order to evaluate the desirability of efforts to increase the walleye population without concurrent increases in forage fish populations (Rudstam et al. 1996).

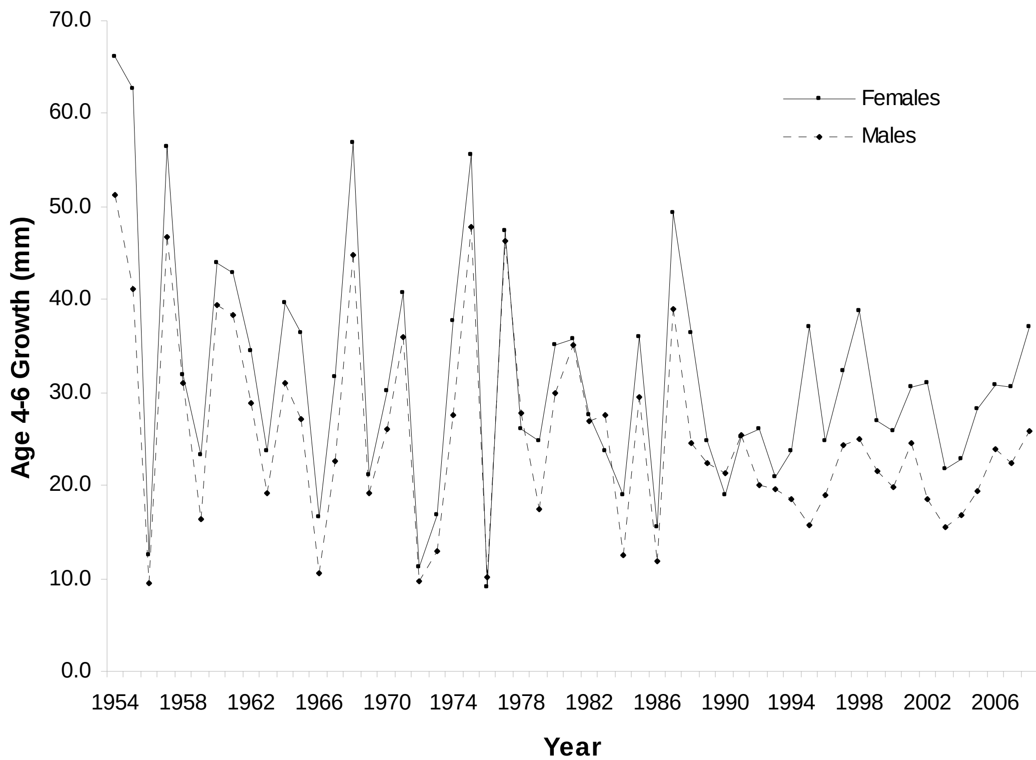

Figure 8. Growth index for walleye in Oneida Lake, New York, 1954-2008 (geometric mean growth in length (mm) of age 4-5, 5-6 and 6-7 fish).

The Oneida Fish Cultural Station (OFCS) stocked 153 million walleye fry in spring 2009. The CBFS Miller sampler estimate of larval walleye density is conducted together with our first estimate of yellow perch larvae (at 8 mm length). In 2009, the survey was initiated on 15 May. Larval walleye were 11.3 mm in length at that time. In several past years, walleye were assessed earlier when average lengths were approximately 9 mm (9.4 mm, range 9.0-10.2 mm, N=18). In years when both the 9 mm survey and the values from the yellow perch 8 mm survey were available, the two surveys are correlated (r^2 = 0.58, P = 0.010, N=10). With one outlier removed

(2002, when few stocked walleye larvae survived a cold period after an early stocking date) the correlation improves ($r^2 = 0.88$, $P = 0.0002$, N=9). The equation is

$$WD_{YP} = 203.6 + 0.722\ WD_{9mm} \qquad (2)$$

where, WD_{YP} is walleye density at the 8 mm yellow perch survey, WD_{9mm} is walleye density at the 9 mm survey, both in fish/ha. Our walleye larvae index (Appendix Table A4) is the number of walleye larvae at the time of the 8 mm yellow perch survey, either measured directly (N=15) or calculated from the 9 mm survey with this equation (years 1966, 67, 69, 99, 2000, 03, 04). The walleye larval abundance in 2009 was 907 fish/ha which is substantially lower than the long term mean of 1,545 larvae/ha (23 years, 1966 – 2007). There is a time trend of increasing larval walleye abundance over the entire time series, but no significant trend over the last decade (Table 2).

Age-0 walleyes are monitored with weekly bottom trawls at 10 standard stations from July through October. Catch per unit effort is translated to density in fish/ha assuming that each trawl samples an area of 0.1 ha. Trawling in 2009 started on July 22 and continued through October 19. The 2009 age-0 fall walleye density estimate was 1.6 fish/ha on October 1. Average length on October 1 was 155 mm. Abundance was very low compared to the long term data, and was the lowest observed since 1976 (Figure 9, Appendix Table A4). These low catches suggest that the 2009 year class will produce few age-4 recruits to the fishery in 2013. Long-term trends show a significant decline in fall density of age-0 walleye despite the increasing trend in larval abundance (Table 2). Over the last decade, there is no detectable trend in fall age-0 walleye density, suggesting that first year survival of young-of-year walleye may have more or less stabilized at a level well below what was observed in the 1960s-1980s (Table 2). During recent years, poor walleye year classes are more common and those years that do produce more than average numbers of fall age-0 fish represent much smaller year classes than observed prior to the 1990s when zebra mussels established in the lake (Figure 9).

The 2008 year class was modest compared to the historic record but still the fourth largest of the last decade (Figure 9). October mean length was relatively small (average 130 mm). Spring abundance of the 2008 year class as age 1 in the 2009 was 3.7 fish/ha, substantially below the long-term average of 30 fish/ha in the spring, and the second lowest number obtained since 1999 (Figure 10). Long-term trends in spring yearling walleye density show a significant decline (Table 2). Similarly, densities of yearling walleye in the spring have continued to decline significantly over the last decade (Table 2). While the long-term decline in yearling walleyes is consistent with the long-term trends towards lower fall densities at age-0, the decline in yearling catches over the last decade has been observed despite more or less stable densities of age-0 fish in the fall. This suggests that overwinter mortality may be increasing for young walleye, which, combined with relatively low numbers of age-0 walleye, further reduces the odds that large year classes such as observed in the 1960s-1980s will be produced.

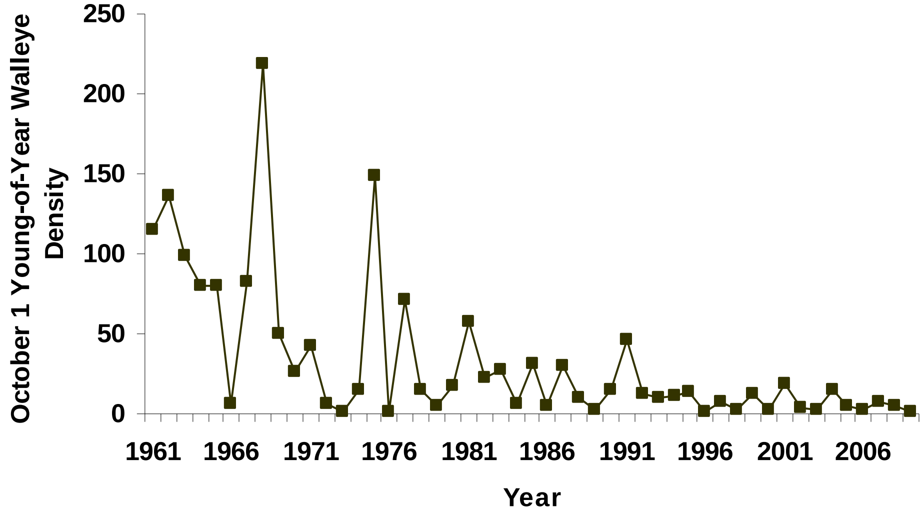

Figure 9. Time trends in density of age-0 walleye on October 1 based on bottom trawls, Oneida Lake, New York, 1961-2009.

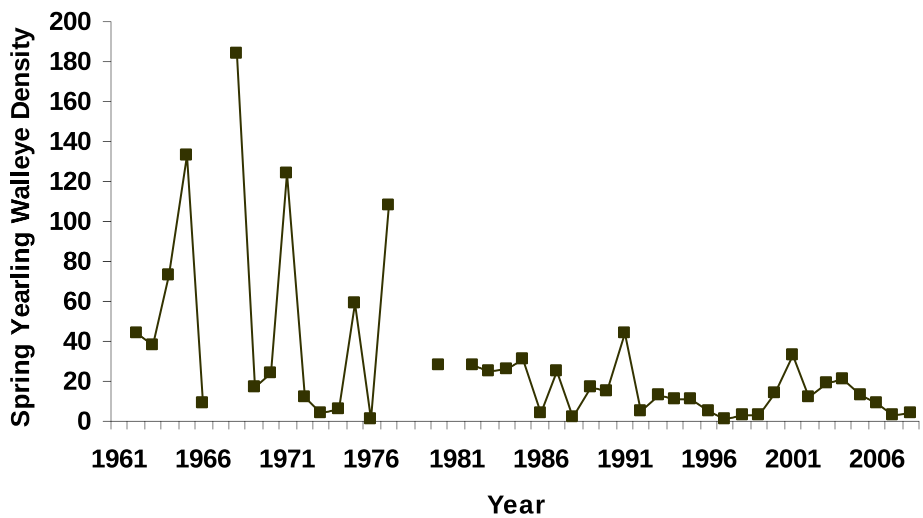

Figure 10. Time trends in density of yearling walleye in May based on bottom trawls, Oneida Lake, New York, 1961-2009.

The adult walleye population in Oneida Lake suffered declines through the 1990s, and the current populations has hovered around 350,000-450,000 fish despite aggressive cormorant management. Survival of age-0 walleyes is low even though the number of larvae present in the spring is high, suggesting that first-year survival is lower now than in the early decades of our monitoring. Overwinter survival also appears to be declining. In the past, first year mortality has been attributed to cannibalism, and this is particularly high when the abundance of age-0 yellow perch is low (Chevalier 1973, Forney 1980). Reduced first year survival may be attributable to higher predation mortality experienced as a result of clearer water following establishment of zebra mussels. Similarly, reduced production of age-0 yellow perch (see below) may increase predation pressure on fingerling walleye. Under current conditions, Oneida Lake may no longer be able to produce the number of walleyes that were present during 1960s to 1990s. Multiple factors likely contribute, including effects of lower productivity, increased water clarity, and changes in the current complement of forage species which include later-hatching gizzard shad and white perch in addition to yellow perch. In addition, increasing numbers of littoral predators such as smallmouth and largemouth bass may increase competition for forage.

Yellow perch

Adult yellow perch numbers are estimated from the catches in standard gill nets and estimates of catchability (Irwin 2008). The yellow perch population in 2009 was estimated to be 808,000 age 3 and older fish, which is the lowest population level since 1999 (Figure 11, Appendix Table A5). While the yellow perch population had been showing a slow increase during the years cormorant hazing was in place, the 2009 estimate is more in line with population levels observed in the late 1990s. Rudstam et al. (2004) predicted the yellow perch adult population to rebound to around 1.6 million fish by 2006 if cormorants were removed in 1998, but declining recruitment has left the population below this level. Because our estimates are based on gill net catches, variability is relatively high between years. Mark-recapture estimates with the method we used in the past are no longer practical for yellow perch because too few fish can be marked in the spring and estimates based on low numbers of marked fish have as much uncertainty as estimates based on gill net catches. Long-term trends show a significant decline in adult yellow perch population size, but no trend is detectable over the last decade, suggesting a more or less stable, but much smaller population than was present in the lake in the1960s-1980s (Table 3).

Table 3. Comparison of long-term (1975-2009) and recent trends (2000-2009) in measurements of yellow perch abundance in Oneida Lake. Significance levels are based on simple linear regression using JMP 7.11. Data are presented in Appendix Tables A5.

	Long-Term			Last Decade		
	1975-2009			2000-2009		
Variable	Trend	r^2	*P*	Trend	r^2	*P*
Adult (age 3+) population size	**-**	0.42	**<0.0001**	-	0.04	0.59
Larval density	**-**	0.08	**0.06**	+	0.58	**0.01**
October 1 age-0 density	-	0.22	**0.0007**	-	0.02	0.74
Spring age-1 density	NT	0.01	0.40	-	0.06	0.43

Summer age-1 density	-	0.08	**0.05**	NT	0.03	0.68

Our predictions of future recruitment to the adult population from catches of age-1 perch in bottom trawls are based on a relationship established prior to cormorants establishing on the lake (Rudstam et al. 2004). While this relationship was unreliable when cormorants were established on the lake, it is applicable under the current scenario of full season cormorant hazing. Using the pre-cormorant regression, we predict that the year class of 2007 will yield 234,000 fish to the adult yellow perch population in 2010 and the year class of 2008 will yield 393,000 adult perch in 2011. With these modest year class projections, it is unlikely the adult yellow perch population will exhibit significant increases in the near future.

We measure the abundance of yellow perch at the larval stage (two surveys - 8 and 18 mm), in bottom trawls through the summer, and again in the trawls centered on May 1 (Appendix Table A6). We use the decline in catches in the bottom trawl to estimate age-0 yellow perch abundance on Aug 1 and Oct 15. Larval yellow perch density in 2009 was the third highest observed since 1982 (Figure 12). Fall density of the 2009 yellow perch year class (estimated from mean of final 3 trawl surveys, as the catch curve did not show detectable mortality to allow estimation by the traditional method) was 1454 fish/ha, the second highest we've observed since 1985 (Figure 13). We also saw a large year class of yellow perch in 2007, but overwinter mortality was apparently high, and we will have to determine if the large 2009 year class exhibits better survival. Spring yearling catches of yellow perch from the 2008 year class were the lowest in four years (Figure 14). Long-term numbers show that the yellow perch population has exhibited a significant decline in larval production, fall age-0 densities and summer catches of age-1 fish (Table 3). As with walleye, the last decade has shown some moderation of the declining trends observed over the long-term, suggesting that recruitment of yellow perch may have reset at new, lower, annual levels than observed during the 1960s-1980s. Under this scenario, significant increases in the population of adult yellow perch in Oneida Lake may not be realized. In light of relatively poor growth of adult walleye, potentially resulting from lower availability of age-0 yellow perch, it may be desirable to investigate ways to build up the yellow perch population prior to efforts directed at increasing walleye numbers.

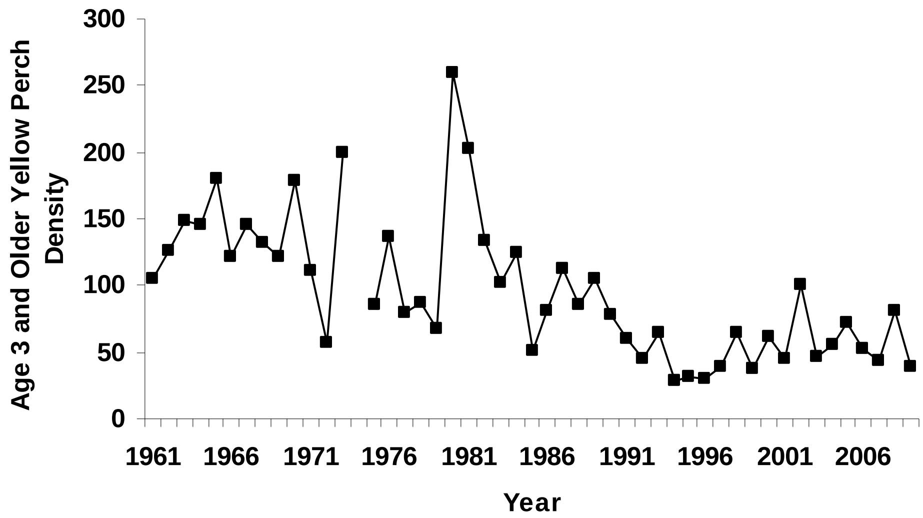

Figure 11. Time trends in age 3+ yellow perch densities (#/ha), Oneida Lake, New York, 1961-2009.

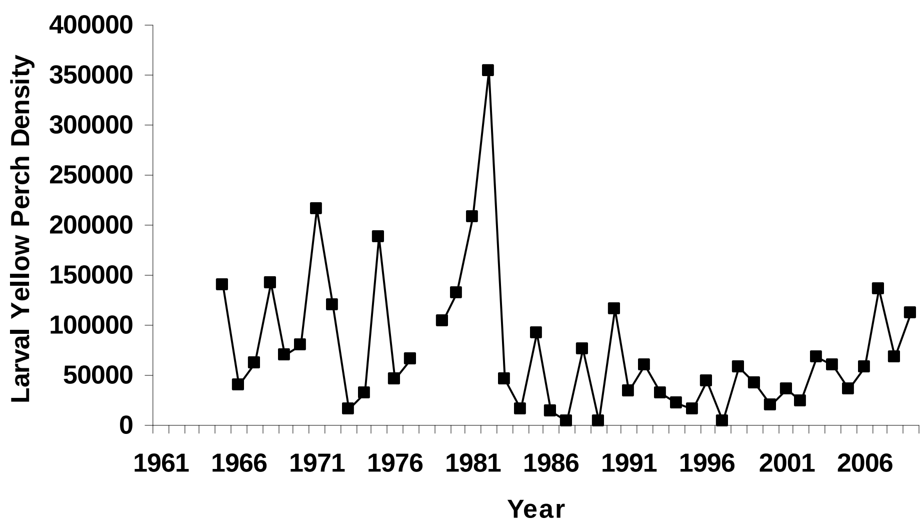

Figure 12. Time trends in age larval yellow perch densities (#/ha), Oneida Lake, New York, 1961-2009.

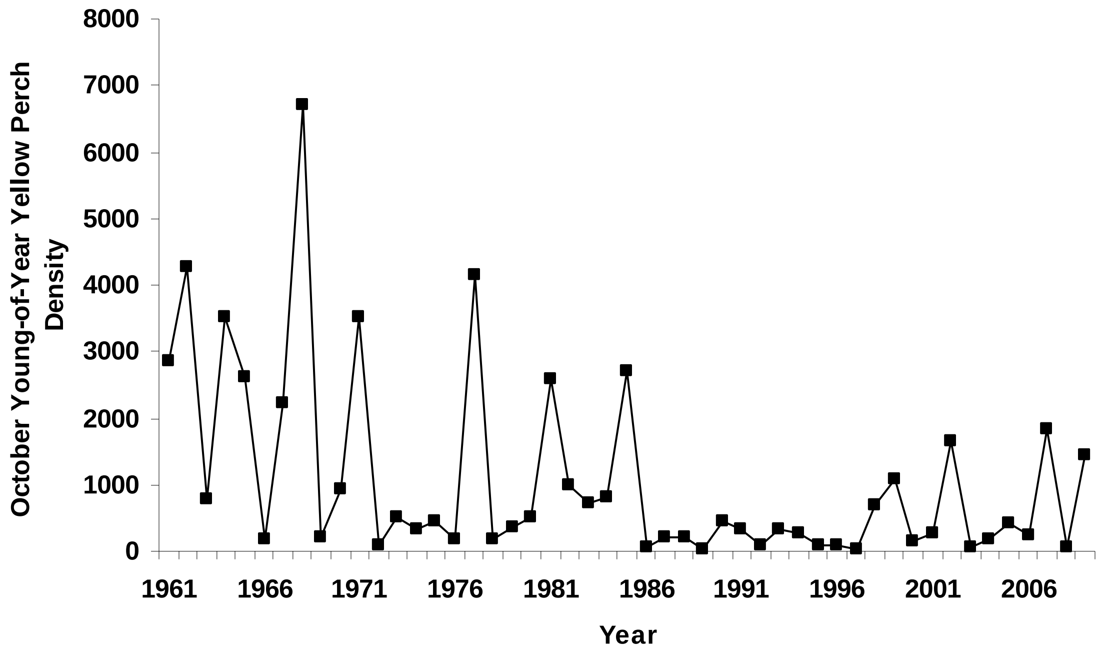

Figure 13. Time trends in fall age-0 yellow perch densities (#/ha), Oneida Lake, New York, 1961-2009.

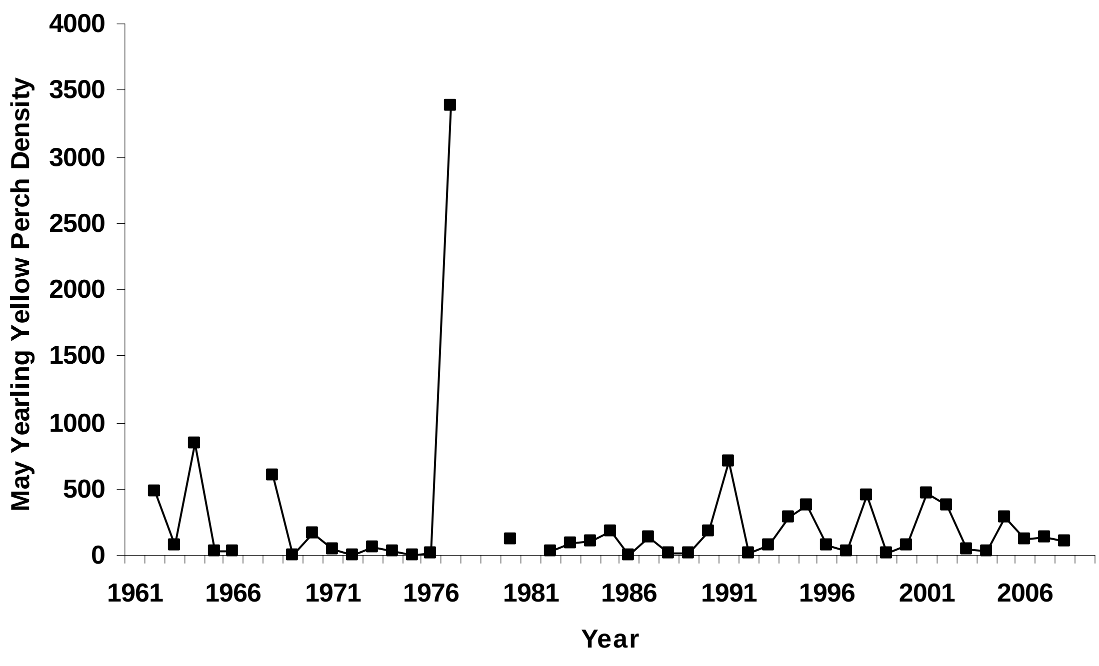

Figure 14. Time trends in spring age-1 yellow perch densities (#/ha), Oneida Lake, New York, 1961-2009.

White perch

Based on gill net catches, the white perch population in Oneida Lake has been increasing steadily since the mid-1990s. In 2009, white perch catch exceeded yellow perch for only the second time on record (prior occasion was 2007; Figure 15; Appendix Table A7). Recruitment is variable and poorly correlated with abundance of age-0 fish caught in bottom trawls in September – October, but white perch have produced age-0 catches suggestive of successful year classes at least once every three years over the last decade (Figure 16). Young white perch are known to be sensitive to cold winters (Johnson and Evans 1991), but we were not able to correlate over-winter survival with ice duration in Oneida Lake (Fitzgerald et al. 2006). The low recruitment years from 1988 to 1994 may be related to a disease that caused large kills of adult white perch in 1987 and 1988, but the population now appears to be growing (adult gill net catch over last ten years has increased significantly, $r^2 = 0.43$, $P = 0.04$) despite stable production of young-of-year (YOY trawl catch trend over last ten years, $r^2 = 0.002$, $P = 0.89$). White perch diets are similar to yellow perch, although they appear to feed more on larval fish early in the season. Increases in white perch could therefore be part of the explanation for increased early mortality of larval percids.

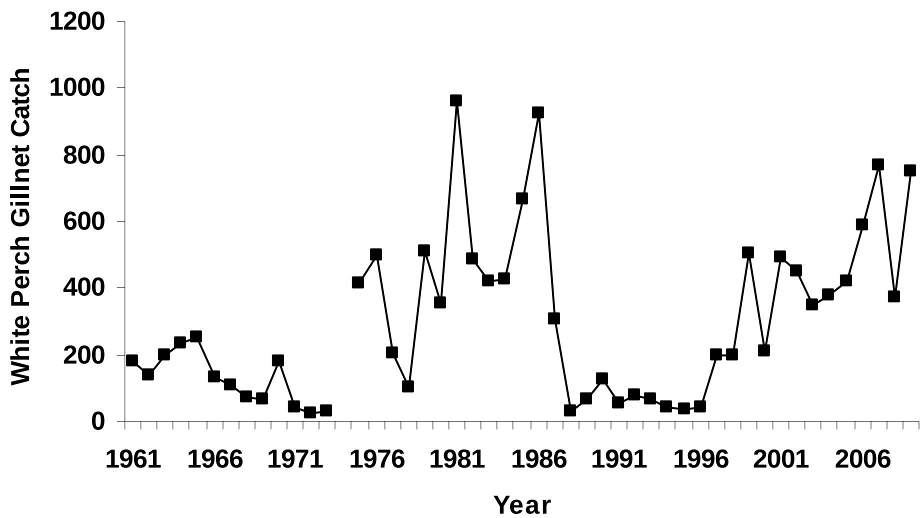

Figure 15. . Time trends in gill net catches of white perch, Oneida Lake, New York, 1961-2009.
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Smallmouth bass

Smallmouth bass have become an increasingly important sport fish in Oneida Lake, and can also have large effects on littoral fish communities when abundant (VanderZanden et al. 1999, Lepak et al. 2006). Catches of age-0 smallmouth bass were among the highest on record in our bottom trawl in both 2007 and 2008, but were low in 2009 (Figure 16). Catches of adult smallmouth bass in standard gill nets also declined in 2009 (Figure 17). We expect that the year classes of 2007 and 2008 will contribute to increased catches in gill nets. Our long-term data series shows that smallmouth bass catches have increased significantly since 1960 (YOY trawl catches – $r^2 = 0.18$, $P = 0.002$; adult gill net catch – $r^2 = 0.47$, $P < 0.0001$). Over the last decade, we have observed a modest continuing increase in young-of-year catches ($r^2 = 0.28$, $P = 0.12$), but no trend in adult catches ($r^2 = 0.001$, $P = 0.92$). It appears that changes in lake condition, likely both clearer water facilitating foraging and warmer summer water temperatures contributing to increased year class success have allowed the smallmouth bass population to reach a higher level than observed in the 1960s-1980s. While we do not necessarily expect to see continued growth of the smallmouth bass population, we anticipate they will continue to be an abundant and important species in the lakes ecology and fisheries. We are investigating diets of smallmouth bass monthly from June through October (Fetzer PhD thesis). Although fish (age-0 and age-1 yellow perch, age-0 gizzard shad) are common, the diet of smallmouth bass also consists of invertebrates like crayfish. Walleye are more piscivorous than either black bass species in Oneida Lake. We did find an age-0 walleye in a smallmouth bass stomach in June 2008, but the number of young walleye in the black bass diets (both species) is substantially less than the number found in adult walleye. More detailed analysis of this data set is part of Fetzer's PhD thesis.

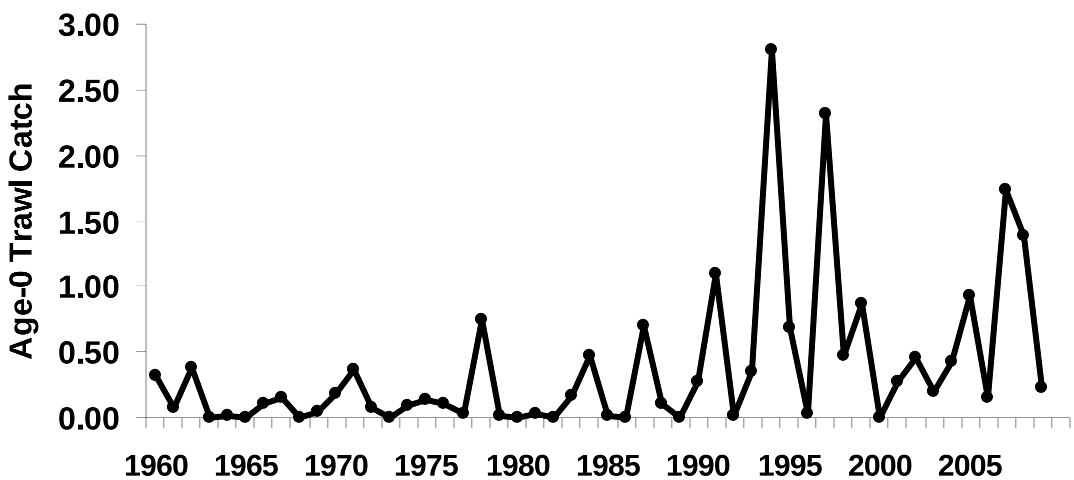

Figure 16. Time trends of age-0 smallmouth bass catches in bottom trawls, Oneida Lake, New York, 1960-2009.

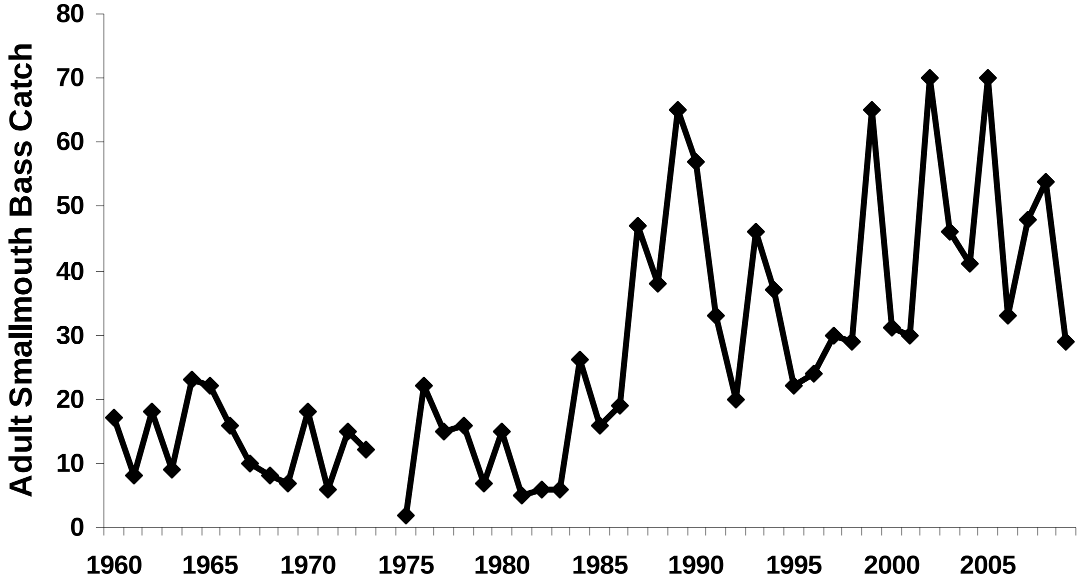

Figure 17. Time trends of adult smallmouth bass catches in gill nets, Oneida Lake, New York, 1960-2009.

Open water forage fish (gizzard shad and emerald shiner)

Pelagic fish biomass was estimated in 2009 the first week of September. Total pelagic fish density was estimated to be 8,500 fish/ha of which 1000 fish/ha were age-0 emerald shiner *Notropis atherinoides*, 1500 were age-1 emerald shiner, and 6000 were gizzard shad (Appendix Table A8). Biomass was estimated at 24 kg/ha, of which 18.8 kg/ha was gizzard shad. The abundance of gizzard shad was up more than 100% from 2008. Cool summer temperatures resulted in slow growth and biomass was only 32% higher than in 2008. Few shad appear to survive the winter in Oneida Lake, and most adult gizzard shad in Oneida Lake are still from the 2005 year class, when the weight of age-0 shad in September averaged 21.6 g and the winter was relatively mild. Gizzard shad were the most common diet item of walleye in October 2009, and may provide some buffering of reduced availability of yellow perch as walleye enter the winter (Appendix Table A3). Observed abundance of gizzard shad over the last decade shows no significant trends ($r^2 = 0.03$, $P = 0.46$).

Sturgeon

May lake sturgeon *Acipenser fulvescens* catches from directed sampling with large mesh gill nets increased modestly from those observed in 2008 (Appendix Table A9). The May gill net catch per hour in 2009 was 0.20/h. June catches (0.14/hr) were comparable to those observed since 2005. Sturgeon likely do not begin to fully recruit into our nets until age-5 or older, and out-migration does take place, so catches from the year classes stocked between 1995 and 2000 might be expected to exhibit declines. New year classes recruiting to the gear will be the small 2003 stocking (368 fish, average total length 233 mm) and a larger 2004 stocking (1200 fish, average total length 187 mm), reached age-5 in 2008 and 2009. As a result of these new recruits to the population, we would expect recruits to potentially offset losses of older fish and may see increases in spring gill net catches over the next several years. Length and weight data from collected sturgeon still indicate a population with fish in excellent condition that are growing at high rates. Fish over 140 cm total length (TL) are routinely encountered and one fish over 38 kg was captured in 2010. We still have not seen evidence of ripe females or attempted spawning, but efforts to survey potential spawning areas in the spring have not been undertaken. There have been tag returns from fish running up spawning streams (Fish Creek). Males appear to reach maturity in Oneida Lake at age 8, so several year classes of mature males are now present in the lake. A telemetry project funded through the State Wildlife Grants Program is anticipated to start in 2011, and should allow closer investigation of potential spawning activity.

Double-crested Cormorants

The double-crested cormorant population was hazed by USDA Wildlife Services on Oneida Lake throughout the 2009 season, continuing a program initiated in 1998 and expanded in 2004. The population goals established by NYSDEC for 2004 to date included 100 adult cormorants and 20 active nests, with no successful hatching. In 2009, cormorant counts averaged 97 birds in April and May, around 107 birds in June and July, and 172 in August through October. Diets of 163 cormorants collected by USDA APHIS NY Wildlife Service personnel from April through October were examined by CBFS staff. Of the 986 identifiable items recovered from stomachs, summer diets were dominated by yellow perch (59%) followed by *Lepomis* (15%) and rock bass (11%). Walleye comprised 2% of summer cormorant diets. Fall diets were predominately composed of gizzard shad (77%), yellow perch (14%) and emerald shiner (5%). Young-of-year gizzard shad did not appear in cormorant diets until late July and August. Given the importance of gizzard shad in cormorant diets in the fall and the low cormorant abundance throughout the summer, cormorants should not have had a measurable effect on percids in 2009.

2008 Nearshore Sampling

Since 2007, we have sampled 24 sites around the lake representative of nearshore habitat types. Sites were selected to represent the common substrates in the nearshore in the proportions they occur and distributed around both shores of the lake as evenly as possible while still achieving Each site is sampled via 24 hour sets of a fyke net comprised of a 0.9 m x 1.5 m frame fitted with 12.7 mm (1/2”) delta knotless mesh. In 2008, we concurrently sampled 14 sites with a fyke net comprised of a 0.9 m x 1.5 m frame fitted with 5 mm (1/4”) delta knotless mesh In 2009, all 24 sites were sampled with nets of both mesh sizes.

The 2009 nearshore fyke net survey was conducted between 16 September and 9 October. Twenty-two unique species were captured by the ½” mesh nets and 23 in the ¼” mesh nets (Appendix Tables A10 and A11). With few exceptions, catch rates in the ½” mesh nets for most common species were similar to rates observed in past years, with no observed increases or decreases in catch rates beyond what would be expected due to normal sampling variability, although catches did indicate a large year class of *Lepomis*. Catch rates of YOY smallmouth bass were lower in 2009 than in 2008, similar to trends observed in the bottom trawl samples. Sampling under the new protocol will continue in 2010.

Recommendations for management and future research directions.

In past years we have identified several ongoing ecological changes that are likely to affect the fish community in Oneida Lake. These included climate warming, species invasions, and increased water clarity. The data collected in 2009 are consistent with previous indications that the lake has undergone fundamental changes in physical characteristics and productivity at the lower trophic levels. Water temperatures and ice duration continued to reflect warmer conditions than when studies were first initiated, water clarity remained well above long-term means, and a new invader was documented in the lake (*Hemimysis anomala*) (Brooking et al. 2010). Oneida Lake presently fits the characteristics of a mesotrophic system, with reduced nutrient inputs and primary production from early decades of our studies when it was classified as eutrophic. Much of the productivity has shifted from the pelagic to the littoral zones, including dramatic increases in littoral macrophytes, with concomitant increases in nearshore species. Clearer water conditions appear to have reduced survival of pelagic walleye and yellow perch fry, resulting in lower average year class size and recruitment to subadult stages than was typical of the lake before major ecological changes were observed. Cormorant predation on subadult stages resulted in decreases in recruitment to the fishery, and the establishment of a cormorant management program contributed to increases in adult walleye numbers, but we have not seen anticipated increases in adult yellow perch numbers. While the lake supports an excellent fishery for walleye, and should continue to do so under present conditions, our analyses suggest that recruitment is no longer sufficient given current harvest rates to expect the population to rebuild to levels observed in the 1960s and 1970s. Similarly, yellow perch recruitment has also declined to a new, lower, average level in the last decade, and it is likely that the adult perch population will also stay well below its historic highs. If yellow perch densities are in part limited by productivity, it is also possible that increases in the white perch population may also act as a constraint on the size of the adult yellow perch population. Smallmouth bass have benefited from changes in the lake, and the population has reached higher levels than were observed in the 1960s and 1970s, and there is no reason to think this will not remain the case. Oneida Lake offers diverse, high quality fishing opportunities, and should continue to do so, but all indications are that the fish community has changed as a result of larger ecological events, and it does not appear practical to use benchmarks established in the 1960s and 1970s as gauges of what is realistic today.

Future invasive species are possible, including the round goby (*Neogobious melanostomus*), the spiny waterflea (*Bythotrephes longimanus),* and the fish hook waterflea (*Cergopagis pengoi*). Continuing analysis and monitoring of the Oneida Lake data set should not only give us information on the response to these ongoing ecological changes of lakes and fisheries that are relevant to Oneida Lake, but also to the northeastern US and southeastern Canada. A baseline data series is essential for evaluating system responses to ecological change. In addition, we are evaluating cormorant-percid interactions by observing the response of the Oneida fish community, in particular walleye and yellow perch, to the removal of most cormorants from the lake. This represents a whole lake management experiment, and it is important that this effort is evaluated thoroughly. We have an opportunity to do adaptive management as it was intended (Walters 1986) by making monitoring and evaluation an integral part of management. It is also important because similar cormorant management activities are planned for other lakes in the US and Canada.

In the short term, we do not believe that a goal of increasing walleye abundance in Oneida Lake much higher than the 400,000 fish currently in the lake is realistic. While adult walleye growth rates improved in 2009, growth rates in recent years have been relatively low, and higher abundance may lead to further declines in growth rates and likely limit recruitment of both walleye and yellow perch. Of course, if growth rates increase in the future, this recommendation should be revisited. If growth rates continue to decline, it may be wise to consider less restrictive regulations. However, our analyses to date suggest that catch rates should increase when walleye growth rate is low, leading to higher angling mortality and decreased population abundance without changes in regulations (VanDeValk et al. submitted).

Recommendation for current management: Fisheries management on Oneida Lake includes stocking of walleye larvae, size and creel limits for walleyes, black bass, and other species, and control of cormorants. We recommend maintaining these efforts and regulations at current levels in 2010-2011.

Stocking of walleye larvae. Continue stocking at current levels. This will maintain a consistent supply of walleye larvae to the lake and makes walleye less sensitive to potential increases in egg predation from a future abundant gobid population. Our best estimates suggest that the number of naturally produced walleye larvae in the lake is about 25% of the numbers stocked.

Size and creel limits for walleye. The adult walleye population is estimated to be 368,000 fish in the spring of 2009 which is similar to 2001-2002. Growth rates of walleye in the lake do not indicate a need for building the current population without first observing improvement in the annual production of yellow perch. Therefore, maintain the current size limit for Oneida Lake walleyes at 15 inches. A 5 fish creel limit can be considered if there is a need to be consistent with statewide regulations, reduction of the walleye population may enhance yellow perch recruitment so that later increases in walleye numbers may be considered.

Cormorant control. We have observed an increase in both the walleye and the yellow perch population concomitant with more intensive cormorant control, although not to historic levels. This suggests that removing cormorants does increase percid recruitment to the fishery. Current more-intensive cormorant control by APHIS has been ongoing since 2004, and we intend to fully evaluate the response of the fish populations to this management action through DeBruyne's PhD thesis. Loss of funding for the cormorant management program in 2010, and possibly into the foreseeable future is of concern. Our data do show that a rebuilding of cormorant numbers will likely reduce subadult walleye and yellow perch survival, and potentially reduce populations to the point where current harvest rates are not sustainable.

Given the result and discussion in this report, we recommend the following research and monitoring activities in 2010:

1) Continue standard sampling program. This program includes two larval fish sampling surveys (8 and 18 mm yellow perch surveys), 15 standard gill nets, weekly trawl surveys from August 1

through October, pelagic prey fish survey with acoustics, midwater trawl and pelagic gill nets at the end of August, fyke net sampling for nearshore fish in September, and large mesh gill nets for sturgeon. We recommend that the next walleye mark-recapture estimate be conducted in 2010.

2) Examine the yellow perch data set for patterns in mortality using modern estimation models (ADmodel Builder). This is part of Robin DeBruyne's PhD thesis.

3) Continue the evaluation of cormorant management on percid populations including publication of chapters in Jeremy Coleman's PhD thesis and the analysis of PhD student Robin DeBruyne. This is a collaborative project with USDA-APHIS.

4) Finish analysis of creel survey techniques (Krueger M.Sc. thesis).

5) Increase attention to the effect of alternative prey fish species on the interaction between walleyes and yellow perch and the importance of changing spatial distributions for age-0 yellow perch survival (Fetzer PhD thesis).

6) Institute a spring centrarchid sampling program to complement fyke net sampling as a means to monitor changes in the nearshore fish community. With increases in bass fishing, there is a need to establish an index of adult bass populations.

7) Develop a low cost creel survey for monitoring of catch rates and angler use of the lake

8) Develop a sampling strategy to monitor changes in littoral macrophyte coverage in the lake.

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Appendix 1: Data collection methods

Limnology. Zooplankton samples are collected weekly (May-October) from 2-5 sites with a 153 um mesh nylon net (0.5 m diameter) using a vertical tow from 0.5 m above the bottom to the water surface. Samples are preserved in 70% ethyl alcohol (8% sugar-formalin solution 1975-1996). Zooplankton are identified, counted, and measured (to the nearest µm) using a digitizing tablet and microscope (1998 – present). Previous methods include use of a dissecting microscope and calipers (1975-1982), and a touch screen setup with computer-assisted plankton analysis system WSAM (1983-1997) (Hambright and Fridman 1994). Seasonal mean biomass is calculated from weekly averages. Integrated water samples for total phosphorous (TP) and soluble reactive phosphorous (SRP) are collected using a 1.9 cm inside diameter Nalgene tube lowered to a depth of 1 meter above bottom, and frozen for later analysis. In the lab, a 50 mL aliquot of unfiltered water is analyzed for TP using the persulfate digestion method (Menzel and Corwin 1965). For SRP, lake water is filtered through a Whatman 934-AH glass fiber filter and a 50 mL aliquot is analyzed using the molybdate method of Strickland and Parsons (1972). For chlorophyll-*a* measurements, lake water (up to 2.0 L) is filtered through Whatman 934-AH glass fiber filters and the filters are assayed using the acetone extraction method (Strickland and Parsons 1972). Annual averages are calculated as the average of weekly values at 2 to 5 stations from May to October. All 5 stations are included when available, except for Secchi depth from the shallow station (Three Mile Bay) because the Secchi disk is sometimes observed on the bottom.

Larval fish surveys: Miller high-speed sampler surveys are designed to estimate abundance of larval walleye and yellow perch. Larval walleye and yellow perch are sampled when yellow perch reach approximately 8 mm and again at approximately 18 mm. For each survey, the lake is divided into two or more horizontal and vertical depth strata and samples taken at a total of 46 randomly selected sites within designated strata. At each site, four Miller samplers are towed simultaneously at different depths and catches are pooled by stratum. Distance towed is about 1.6 km at a speed of 3.6 m/s. Larval fish captured are identified, counted, and measured. Density estimates are calculated for each strata based on catch and volume of water strained. Catches of yellow perch in the 18 mm survey are adjusted for size-specific gear avoidance (Noble 1970).

Gill net surveys: Standard gill net catches provide an index of the adult walleye and yellow perch populations as well as relative abundance estimates of various other species. A variable mesh multifilament gill net is fished overnight at a different standard site each week for 15 consecutive weeks starting in the beginning of June and continuing through mid-September. The net consists of four gangs 45.75 m long by 1.83 m deep sewn together to form one 183 m long net. Each gang consists of six 7.6 m panels with 38, 51, 64, 76, 89 and 102 mm stretch mesh. The net is set around sunset, fished on the bottom, and retrieved in the morning at about 07:30. The time fished varies somewhat with season but has been identical for each location each year. All fish (or a subsample of at least 60 individuals of a species) are measured (total length in mm), weighed (g), sexed, stomach contents recorded, and scales taken. Large mesh gill nets were used to monitor sturgeon reproductive status and abundance and growth in 4 different substrate types. Variable (152, 203, 254, and 305 mm stretch mesh) mesh monofilament gill nets 61 m in length were set for approximately 4 hours at 12 sites monthly in May and June. All sturgeon caught were examined for tags, measured, weighed, a fin ray section removed for age determination, diet recorded using gastric lavage, tagged with both a Carlin dangler tag and PIT tag, and released.

Trawl surveys: The catch in trawls provides an estimate of year class abundance for young-of-year (age-0) and yearling walleye as well as prey species, primarily young yellow perch. Trawling begins around the middle of July when age-0 yellow perch become demersal (at about 1 g in weight) and weekly surveys continue until three October surveys are completed. A 5.5 m otter trawl is towed for 5 minutes, sampling approximately 0.10 ha per haul. Ten standard sites are sampled in each survey. Age-0 fish are identified, counted, total weight by species recorded to the nearest gram, and a subsample of fish measured for length. Lengths are recorded and scale samples taken on all older fish.

Hydroacoustic surveys: Pelagic fish biomass is estimated in the end of August–beginning of September using hydroacoustics. Surveys are conducted using a 123 kHz split beam unit (Biosonics DT-X, pulse length 0.4 ms, 7.8^{o} beam width) along a set of transects from the east to the west ends of the lake. Surveys are typically conducted during two consecutive nights starting one hour after sunset. Acoustic data are analyzed with EchoView (v4.7 in 2009). Echograms are checked for problems associated with poor bottom detection, bubbles from waves, echoes from macrophytes, and other sources of noise. Questionable areas are removed from the analysis. Attempts are made to sample as close to the bottom as possible by re-defining the bottom at high magnification when needed. All densities are calculated from in situ backscattering cross section (average for targets larger than –60dB) and echo integration according to the standard operating procedure for Great Lakes acoustics (Parker-Stetter et al. 2009). Noise level at 16 m, the maximum depth in Oneida Lake is estimated to be –85 dB (uncompensated TS) thus satisfying a 15 dB signal to noise ratio throughout the water column for the smallest targets included in the analysis as recommended by Rudstam et al. (2009). Analyses are conducted using each transect as cluster of elementary sampling units 500 m in 2008 (1000 pings in some years – approximately 520 m). Cluster analysis was used to estimate mean density and standard error using standard formulas (Scheaffer et al. 2006) and a program available on the web site "Acoustics Unpacked" (www.acousticsunpacked.org, Sullivan and Rudstam 2008).

Fish are sampled in association with acoustic surveys using a midwater fry trawl and fine mesh gill nets. These gears are used to assess the species composition of young fish in the pelagic zone. The trawl measures 2 m x 2 m at the mouth and is mounted in a metal frame. The first 2 m of the net is comprised of 12.7 mm stretch mesh, the next 2 m of 6.4 mm stretch mesh, and the cod end of the net consists of a 0.5 m plankton net and bucket with 1 mm mesh. At each site, one haul divided into 2.5 minutes at 4.3 to 6.1 m depth and 2.5 minutes at 2 to 3.8 m depth (determined from rope angles) and a second 5 minute haul at the surface (sampling the top 2 m of the water column) are conducted. Two trawl hauls are completed at each of 10 sites, and fish are preserved in formalin and returned to the lab for species identification, enumeration, and measurement. Fine mesh gill nets, 21 m long, are set either on bottom or suspended from the surface. Each gill net consists of seven 3 m wide by 6 m deep panels of different mesh sizes (6.2, 8.0, 10.0, 12.5, 15.0, 18.7 and 25.0 mm bar mesh). Paired (1 surface and 1 bottom) gill nets are set at each of 4 deep stations, and 4 shallow stations are sampled with only 1 net that samples the entire water column.

Acoustic density estimates are apportioned to emerald shiners, gizzard shad, and other fish based on catches in vertical gill nets and midwater trawls after accounting for the relative length selectivity and effort of the two gears. Fish in the top 2 m of the water column are accounted for by calculating the average density of gizzard shad and emerald shiners caught in the top 2 m in vertical gillnets set.

Appendix 2: Standard data tables.

Table A1. Physical, chemical and biological characteristics of Oneida Lake since 1975. Secchi depth (m), chlorophyll-*a* (µg/L), total phosphorous (TP, µg/L) soluble reactive phosphorous (SRP, µg/L), total zooplankton biomass (µg/L), and *Daphnia* spp. biomass (µg/L) are averages from 2 to 5 stations from May to October. Ice freeze day (day since Dec 1), ice duration and ice out day (day of year) are noted at CBFS and refer to the year of ice break-up. The lake was not completely frozen over in the winter of 2001. Summer temperature (°C) is the average temperature from June to Aug measured every hour at 2 m depth at the Shackelton Point station.

Year	**Secchi**	**Chl-*a***	**SRP**	**TP**	**Zoopl. Biomass**	***Daphnia* Biomass**	**First Freeze Day**	**Ice Duration**	**Ice Out Day**	**Sum Temp**
1975	2.7	9.2	17.7	45.9	101.8	74	no data	no data	87	22.2
1976	2.8	9.9	3.3	29.4	192.2	162.4	19	99	87	20.6
1977	2.6	11.1	5.2	36.2	136.4	52.7	3	118	90	20.9
1978	2.9	8.1	16.5	44.7	no data	42.4	15	121	105	22.0
1979	3.2	7.6	29.0	56.7	204.9	157.3	29	96	94	19.8
1980	2.6	12.7	10.2	45.2	188.3	143.1	35	91	95	20.4
1981	2.2	11.6	13.6	31.4	173.8	43.8	15	95	76	21.6
1982	2.2	9.0	15.2	48.0	233.9	95.3	20	118	107	20.8
1983	2.5	8.0	21.7	38.6	271.7	152.4	13	74	87	22.3
1984	2.3	9.2	14.8	30.4	251.5	155.1	21	111	101	21.6
1985	2.1	10.5	11.3	38.1	251.3	111	40	79	88	20.4
1986	2.3	10.4	27.5	64.7	325.4	214.1	19	104	92	20.4
1987	2.8	6.5	7.3	27.6	210.4	141.8	35	86	90	21.7
1988	2.6	9.4	17.1	34.6	285.4	140.1	34	91	94	20.8
1989	3.3	5.2	9.4	24.1	262.8	149	16	102	84	21.9
1990	2.4	9.5	4.8	22.0	234	92.9	5	107	81	21.7
1991	2.3	11.7	4.6	23.2	191.1	89.8	31	78	78	23.0
1992	2.7	7.4	1.8	20.1	389.4	231	25	93	102	20.2
1993	3.7	5.1	5.9	15.8	170.9	87.2	24	99	105	21.4
1994	3.6	6.6	6.2	30.4	182.9	111.6	27	113	109	22.0
1995	4.7	3.2	10.0	22.9	269.2	201.3	39	75	97	23.2
1996	3.5	5.4	5.9	19.9	260	177	32	100	101	22.0
1997	3.6	5.3	3.3	14.7	330	178.7	39	88	96	21.6
1998	2.9	5.2	5.2	21.5	180.7	72.9	48	58	86	22.5
1999	3.2	6.0	6.3	15.1	197.1	94.3	33	94	96	23.3
2000	2.9	6.2	4.1	21.5	202.2	134.5	45	63	77	21.3
2001	3.4	5.4	10.4	28.0	302.3	163.1	12	117	103	22.4
2002	3.6	4.8	7.0	27.2	241.8	136.8	no freeze	no freeze	62	23.0
2003	3.7	6.9	9.8	27.0	253.9	144.1	10	104	105	22.2
2004	3.5	7.7	10.8	29.0	306.6	174.7	21	90	95	21.5
2005	4.2	3.8	16.4	29.4	334	180.3	26	97	98	24.2
2006	3.1	7.3	10.6	29.2	235.1	106	18	72	91	22.9
2007	3.5	6.2	6.1	21.1	183.1	90.4	54	71	94	22.6
2008	4.2	3.8	8.8	22.3	169.4	70.8	19	83	92	22.5
2009	3.8	4.1[1]	5.9[2]	NA	119.6	50.1	24	85	81	21.7
Average[3]	3.1	7.5	10.5	30.4	236.1	130.3	25.7	93.3	92.5	21.8

[1] September and October samples not yet analyzed.
[2] Shackelton Point site only.
[3] Averages for 1975-2008, data for 2009 will not be included until analyses are complete.

Table A2. Walleye age-specific density estimates since 1957 (in fish/ha). Age 1, 2 and 3 are estimated from the average of trawl and gill nets estimates using catchabilities in Irwin et al. (2008). Bold values are from mark-recapture estimates. Densities of walleyes for intervening years were approximated from the mortality between successive biannual population estimates. Estimates from 1978-1987 and 1992-1994 from (Irwin et al. 2008). Estimates for age 4 and older in 2008 are based on the 2007 mark-recapture estimates assuming 15 % mortality of each age class.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age ≥7	Total (age-4<)
1957	no data	no data	no data	**0.4**	**6.22**	**0.97**	**4.62**	**12.21**
1958	9.18	1.55	4.72	**37.82**	**0.6**	**6.12**	**5.59**	**50.13**
1959	0.60	12.23	3.72	**2.69**	**34.12**	**0.27**	**9.47**	**46.54**
1960	4.94	3.62	22.70	**1.8**	**2.36**	**15.74**	**4.8**	**24.7**
1961	27.87	18.72	4.76	**20.82**	**2.45**	**2.14**	**14.9**	**40.31**
1962	15.84	14.49	12.62	**3.15**	**13.93**	**1.71**	**10.35**	**29.14**
1963	24.58	16.31	17.92	**13.26**	**2.56**	**15.32**	**7.61**	**38.75**
1964	34.61	19.28	10.36	9.03	8.85	1.71	15.29	34.88
1965	43.68	19.15	12.78	**8.69**	**5.53**	**7.18**	**10.53**	**31.93**
1966	22.09	31.64	15.05	11.61	7.1	4.52	14.48	37.71
1967	3.99	19.27	29.23	**10.29**	**8.17**	**3.77**	**10.42**	**32.66**
1968	22.35	2.89	20.67	**17.37**	**5.66**	**3.88**	**8.88**	**35.79**
1969	93.66	31.11	4.87	12.74	13.83	4.65	9.44	40.65
1970	3.10	37.77	10.75	**1.18**	**8.41**	**9.53**	**9.05**	**28.16**
1971	4.07	0.53	8.00	9.53	1.01	5.48	12.1	28.12
1972	80.32	9.21	1.54	**23.09**	**6.19**	**0.86**	**11.42**	**41.55**
1973	0.65	43.68	4.58	1.41	12.63	3.63	7.17	24.84
1974	6.08	2.18	47.64	**0.37**	**2.65**	**2.52**	**3.48**	**9.02**
1975	1.56	3.68	1.08	29.91	2.6	0.36	5.88	38.76
1976	92.71	3.61	3.23	**1.08**	**27.76**	**2.11**	**5.06**	**36**
1977	0.70	55.05	2.56	**1.92**	**0.49**	**15.08**	**3.9**	**21.39**
1978	36.75	0.96	31.26	1.56	1.64	0.36	16.67	20.24
1979	3.35	30.20	1.04	22.17	1.24	1.23	11.27	35.91
1980	2.48	4.41	22.30	0.98	14.45	0.81	8.2	24.44
1981	39.70	4.52	5.71	21.39	0.64	9.45	5.87	37.35
1982	26.88	22.72	3.87	3.53	17.5	0.45	10.37	31.85
1983	14.32	33.19	30.66	2.58	2.88	12.55	7.12	25.13
1984	9.79	9.43	20.79	13.77	2.13	2.06	13.33	31.28
1985	10.23	6.85	14.32	26.89	11.68	1.55	10.27	50.4
1986	15.01	9.07	7.03	9.96	22.41	8.7	7.77	48.84
1987	3.09	13.46	6.31	7.89	8.05	16.75	11.13	43.82
1988	105.80	2.14	12.59	**10.34**	**5.02**	**9.66**	**22.32**	**47.34**
1989	3.88	50.90	2.80	8.16	7.58	7.68	13.29	36.71
1990	7.98	8.29	49.85	**1.16**	**5.99**	**5.41**	**14.54**	**27.1**
1991	12.22	7.31	3.91	19.75	2.78	4.84	13.15	40.51
1992	45.62	9.25	6.74	1.79	16.71	1.15	10.45	30.1
1993	3.55	26.66	2.87	1.8	1.42	11.57	7.57	22.35
1994	8.64	2.40	23.14	2.29	1.19	0.98	12.83	17.3
1995	5.81	5.31	1.14	**6.96**	**1.45**	**1.06**	**5.85**	**15.31**
1996	9.66	2.65	2.78	1.49	6.14	0.92	5.37	13.91
1997	3.67	4.82	3.01	**1.57**	**1.2**	**5.39**	**4**	**12.17**
1998	22.17	1.43	4.16	0.7	1.53	1.19	9.51	12.94
1999	13.65	7.68	1.88	**1.54**	**0.57**	**1.44**	**6.86**	**10.42**
2000	9.58	11.81	6.41	0.47	1.95	0.67	7.77	10.85
2001	7.26	12.47	5.99	**3.9**	**0.38**	**2.15**	**6.9**	**13.32**
2002	32.13	9.23	8.39	4.75	3.25	1.41	8.41	17.83
2003	10.87	14.43	3.65	**2.78**	**3.85**	**2.71**	**8.32**	**17.66**
2004	6.39	12.94	12.19	6.14	4.54	2.64	8.23	21.54
2005	8.52	1.59	4.65	**6.15**	**4.97**	**5.53**	**6.05**	**22.71**
2006	5.53	9.68	1.17	1.27	6.87	3.16	11.51	22.81
2007	9.24	6.67	4.41	**1.27**	**1.03**	**7.09**	**9.28**	**18.67**
2008	3.84	3.32	1.29	3.75	1.08	0.87	13.92	19.62
2009	9.25	10.25	8.68	1.1	3.19	0.92	12.61	17.82

Table A3. Fish observed in stomachs of yearling and older walleye taken by trawls and electrofishing during October and November since 1971, expressed as numbers per kg of walleye.

Year	# examined	% empty	YP	Morone	Gizz	ES	Other	Unident	Total
1971	240	37	3.92	0.01	0.00	0.00	0.06	1.59	5.58
1972	163	58	1.02	0.10	0.00	0.00	0.62	0.89	2.63
1973	295	32	0.69	1.36	0.00	0.00	0.43	1.35	3.83
1974	228	27	2.11	1.15	0.01	0.11	0.38	1.76	5.52
1975	204	68	0.20	0.13	0.00	0.02	0.17	0.24	0.76
1976	156	36	1.31	0.89	0.00	0.16	0.75	1.17	4.28
1977	70	19	3.14	1.25	0.00	0.00	0.14	0.89	5.42
1978	85	56	0.51	0.12	0.00	0.00	0.47	0.74	1.84
1981	88	66	1.52	0.16	0.00	0.00	0.00	0.56	2.24
1982	122	11	0.38	5.27	0.00	0.00	0.00	0.54	6.19
1983	117	62	0.19	0.79	0.00	0.00	0.00	0.30	1.28
1984	148	59	0.21	0.45	0.97	0.00	0.07	0.46	2.16
1985	151	50	1.60	0.04	0.36	0.00	0.13	0.44	2.57
1986	193	45	1.60	0.16	0.05	0.00	0.15	0.49	2.45
1987	194	23	0.05	0.64	1.96	0.00	0.02	0.54	3.21
1988	180	55	0.36	0.00	0.30	0.00	0.07	0.33	1.06
1989	193	26	0.00	0.18	5.42	0.00	0.03	0.83	6.46
1990	179	28	0.03	0.00	4.91	0.01	0.00	0.66	5.61
1991	137	20	0.02	0.01	3.81	0.00	0.10	0.77	4.71
1992	65	58	0.17	0.02	0.22	0.00	0.07	0.32	0.80
1993	134	25	2.13	0.51	0.01	0.42	0.81	1.28	5.16
1994	120	55	0.36	0.06	0.71	0.17	0.04	0.75	2.09
1995	86	45	0.44	0.35	0.06	0.02	0.13	0.67	1.67
1996	184	32	0.85	0.37	0.10	0.07	0.52	1.39	3.30
1997	75	45	0.28	0.36	0.00	0.02	0.26	1.15	2.07
1998	78	40	0.28	0.15	0.00	0.10	0.18	0.66	1.37
1999	64	42	0.25	0.03	0.25	0.75	0.03	0.61	1.92
2000	134	21	0.04	0.28	2.32	0.01	0.01	0.92	3.58
2001	123	28	0.40	0.18	0.88	0.17	0.24	0.36	2.23
2002	83	41	0.03	0.04	1.03	0.16	0.03	0.31	1.60
2003	183	39	0.84	0.09	0.36	0.04	0.21	0.52	2.06
2004	135	13	0.30	0.38	2.36	0.57	0.06	0.91	4.58
2005	134	30	1.08	0.11	0.70	0.31	0.13	0.52	2.85
2006	110	25	0.37	0.29	2.50	0.15	0.09	0.51	3.91
2007	264	50	0.87	0.00	0.67	0.02	0.08	0.45	2.09
2008	324	16	0.58	0.08	3.54	0.02	0.08	1.39	5.69
2009	308	44	1.21	0.045	1.63	0.02	0.05	0.26	3.21

Table A4. Young-of-year and age-1 walleye density estimates and mean lengths. Larval walleye density (at the time of the 8 mm perch survey) are from Miller sampler surveys at that time or calculated from the 9 mm larval walleye survey. Age-0 walleye densities (#/ha) and mean lengths (TL, mm) on October 1 are from trawl surveys surrounding the Oct 1 date (50 trawls 9/16 to 10/13 in 2008), and age-1 walleye densities (#/ha) and mean lengths on May 1 are from trawl surveys around May 1 (30 trawls 5/1 to 5/6 in 2008). Densities calculated based on area swept (0.1 ha per trawl) assuming no avoidance.

Year Class	Larval Density	Oct 1 Age 0 Density	Oct 1 Age 0 Length	May 1 Age 1 Density	May 1 Age 1 Length
1961		114.5	140.6		
1962		135.9	142.9	44.2	158.8
1963		98.5	124.2	37.9	153.6
1964		80.6	137.5	73.4	161.3
1965		79.4	153.8	133.0	163.7
1966	1,348	6.3	138.5	9.0	148.1
1967	967	82.4	126.6		
1968	1,580	219.0	143.9	184.2	163.8
1969	559	50.0	142.7	17.0	161.0
1970	2,271	25.8	120.7	24.5	166.7
1971	309	42.0	167.0	124	180.6
1972	1,599	6.0	120.6	12.5	156.0
1973	222	1.6	164.2	4.5	174.0
1974	1,464	14.8	99.6	6	143.6
1975	1,362	148.4	171.2	59	184.6
1976	2,327	1.6	133.2	1.5	158.5
1977	660	71.6	136.5	108	167.8
1978		14.6	123.0		
1979		4.6	145.9		
1980		17.8	154.5	28.0	165.1
1981		57.8	149.4		
1982		22.4	162.0	27.7	175.6
1983		28.0	154.9	25.5	166.8
1984		6.0	132.8	26.3	151.3
1985		31.0	141.0	31.5	159.1
1986		5.4	140.4	3.8	165.3
1987		29.8	176.7	25.0	186.5
1988		10.4	142.3	2.2	146.0
1989		3.0	160.3	17.0	154.2
1990		14.4	173.8	15.0	177.6
1991		46.7	173.2	44.0	175.2
1992	333	12.4	150.4	5.0	157.1
1993		10.4	147.1	13.0	168.2
1994		11.4	130.8	11.5	163.3
1995		13.6	135.4	11.3	165.7
1996		1.8	150.3	5.0	168.3
1997		8.0	158.8	0.7	141.5
1998	275	2.4	207.4	3.0	189.0
1999	1,773	12.4	144.3	2.7	121.8
2000	1,208	3.0	176.5	14.3	180.7
2001	2,541	19.2	153.0	33.0	154.0
2002	213	3.7	173.6	12.3	179.3
2003	986	2.5	139.1	19.5	167.4
2004	3,196	15.3	150.7	21.0	161.8
2005	8,106	5.6	106.5	13.3	143.2
2006	1,304	2.2	163.0	9.3	173.3
2007	942	7.50	131.9	3.3	183.3
2008	5,102	5.40	129.7	0.37	136.0
2009	957	1.6	154.2		

Table A5. Yellow perch density estimates since 1961. Data are from mark-recapture (bold) or based on the catch in gill nets using size specific net selectivity.

Year	Density (#/ha) at age						Total (age3+)
	2	3	4	5	6	>6	
1961	51.2	11.3	56.7	9.4	10.2	17.5	105.1
1962	18.9	38.4	27.8	40.2	12.8	6.5	125.7
1963	15.6	26.7	40.1	32.7	33.5	16.1	149.1
1964	10.5	11.3	45.0	44.4	32.8	12.4	146.0
1965	11.3	44.2	12.7	67.2	41.4	14.1	179.7
1966	34.3	19.6	28.6	20.9	39.2	12.7	120.9
1967	1.4	50.1	28.1	27.2	20.4	20.3	146.0
1968	37.0	3.5	70.2	16.0	17.1	24.6	131.4
1969	33.2	**21.7**	**7.3**	**54.3**	**18.9**	**18.9**	**121.2**
1970	6.7	48.0	23.1	7.5	61.9	37.9	178.4
1971	1.9	**7.7**	**52.6**	**17.1**	**3.0**	**30.2**	**110.7**
1972	41.5	1.8	7.6	26.9	9.0	11.9	57.1
1973	4.6	**144.4**	**3.9**	**7.2**	**17.7**	**26.2**	**199.5**
1974			No gill netting				
1975	39.0	**0.9**	**5.7**	**61.3**	**2.5**	**15.0**	**85.5**
1976	5.3	56.5	2.8	11.2	51.2	14.4	136.1
1977	2.7	**12.9**	**40.0**	**0.5**	**2.2**	**24.2**	**79.7**
1978	19.7	3.9	8.6	41.7	3.6	28.8	86.6
1979	99.1	12.5	5.4	6.1	33.9	10.3	68.1
1980	4.9	179.2	16.3	8.6	14.5	41.3	260.0
1981	16.0	16.3	134.4	23.2	3.7	24.9	202.5
1982	31.2	10.3	10.6	99.6	4.3	8.0	132.8
1983	2.8	27.7	8.2	5.2	54.4	5.8	101.4
1984	18.6	12.6	48.3	17.2	10.3	36.0	124.5
1985	29.8	7.6	5.0	22.2	3.3	12.2	50.3
1986	29.5	24.0	10.3	8.1	28.9	9.0	80.3
1987	15.4	31.7	29.0	11.1	5.0	35.7	112.5
1988	10.0	**15.5**	**24.7**	**18.9**	**4.3**	**21.9**	**85.4**
1989	27.8	7.1	18.6	31.0	23.5	24.2	104.4
1990	8.7	**33.5**	**2.9**	**5.8**	**17.2**	**18.0**	**77.4**
1991	3.4	3.7	18.5	5.9	9.0	22.3	59.4
1992	47.9	5.5	5.2	18.4	6.5	10.0	45.5
1993	29.5	28.2	7.5	4.8	13.7	10.8	65.1
1994	1.7	10.4	8.9	1.5	0.8	6.5	28.1
1995	13.9	**4.3**	**16.1**	**5.9**	**1.4**	**4.0**	**31.7**
1996	26.4	10.7	4.0	8.5	3.6	3.8	30.6
1997	21.3	**26.3**	**7.0**	**1.4**	**2.7**	**1.7**	**39.0**
1998	13.2	23.9	22.0	10.4	4.2	3.9	64.3
1999	4.3	**10.5**	**13.1**	**8.9**	**2.7**	**1.7**	**37.0**
2000	20.3	8.9	15.2	19.4	10.5	7.3	61.4
2001	3.7	**21.5**	**7.1**	**4.8**	**5.8**	**6.5**	**45.7**
2002	5.7	7.9	46.0	11.5	10.7	24.6	100.8
2003	1.7	2.3	7.1	21.7	6.1	9.8	47.0
2004	3.4	5.4	5.5	8.3	17.0	19.5	55.7
2005	2.9	13.4	12.4	4.9	9.2	32.6	72.5
2006	15.5	11.0	12.6	8.1	2.9	18.5	53.0
2007	38.2	15.0	7.1	6.5	3.5	11.7	43.8
2008	14.7	41.7	16.0	5.6	3.7	13.4	80.4
2009	8.3	14.8	12.1	3	5.8	3.4	39.1

Table A6. Young-of-year and age-1 yellow perch density estimates and mean lengths. Larval yellow perch densities (at 18 mm, #/ha) are estimated from Miller sampler surveys. Age-0 yellow perch densities (#/ha), age-0 mean lengths (TL, mm) are estimates for October 15 obtained from regression analysis of weekly catches throughout the season (except in 2009, when catches did not exhibit a significant decline over the summer, so October density is the average of the last three samples). Age-1 yellow perch density are from trawl surveys around May 1 and from mid-July through October (#/ha). Age-1 yellow perch mean lengths are from spring trawl surveys centered on May 1 since 1961.

Year class	Larval density	October age-0		Age-1		
		density	mean length	density spring	mean length	density summer
1961		2,850	60			19.4
1962		4,260	73	486	76	186.8
1963		780	60	71		15.8
1964		3,520	71	849	73	585.9
1965	140,100	2,610	60	30		2.0
1966	40,200	170	73	25	74	39.3
1967	61,200	2,240	72			136.5
1968	141,800	6,700	67	598	75	57.2
1969	69,200	210	65	2		0.5
1970	80,000	930	77	158	85	44.5
1971	216,400	3,520	57	52	62	30.5
1972	120,700	100	67	4	77	0.8
1973	16,600	510	86	63	90	46.0
1974	32,000	320	72	33	74	9.3
1975	188,700	450	65	5	75	4.3
1976	46,600	180	72	12	77	4.8
1977	65,200	4,140	69	3385	70	241.5
1978		180	73			13.5
1979	103,200	360	75			6.4
1980	131,600	500	81	118	81	100.9
1981	208,200	2,590	57			4.6
1982	353,400	980	63	25	68	10.6
1983	45,600	710	79	95	79	26.3
1984	16,000	810	71	103	73	32.1
1985	91,100	2,700	68	174	74	29.8
1986	14,600	70	82	2	84	1.8
1987	3,700	220	68	128	70	97.9
1988	76,200	220	81	19	83	4.5
1989	3,700	20	81	17	82	13.1
1990	117,000	460	73	184	70	121.9
1991	34,000	340	82	705	84	166.5
1992	60,800	100	73	13	79	5.4
1993	32,800	320	85	70	84	56.4
1994	21,800	280	83	281	83	30.1
1995	15,100	90	90	373	89	58.5
1996	43,600	80	80	74	81	24.3
1997	4,600	30	80	23	80	17.5
1998	57,100	700	83	457	84	99.3
1999	42,100	1,080	81	18	84	17.8
2000	19,300	140	78	73	79	7.2
2001	36,200	270	84	466	86	6.3

2002	23,400	1,660	76	380	80	17.6
2003	68,500	60	85	38	84	5.3
2004	60,700	180	86	36	84	5.7
2005	36,300	410	93	280	93	13.5
2006	58,502	240	79	117	79	19.6
2007	135,990	1,842	81	139	85	6.2
2008	67,420	71	73	104	76	2
2009	112,712	1,454	74			

Table A7. Relative abundance of white perch year classes at successive stages of development. Age-0 white perch abundance represented by the calculated density from area swept in trawls in August-September, Age-0 Length is from October trawls, Age-1 Spring is from the CPUE in spring trawls, and age-1 and older are catches in standard gill nets. These values are data for the year of collection. The recruitment index (RI) is the sum of the gill net catch at age 2 and 3 of fish born that year (Fitzgerald et al. 2006). For example the RI value for years 1961 is the sum of the gill net catch of age 2 in 1963 and age 3 in 1964. Bold RI numbers for 1971 and 1972 includes an extrapolation of gill net catches for 1974 when gill nets were not used (see Fitzgerald et al. 2006).

Year	Age-0	Age-0 Length	Age-1 Spring	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6	Age7+	RI	sum GN
1961	1114	84		2	9	20	94	6	8	39	10	178
1962	287	94		0	15	2	34	66	10	13	114	140
1963	54	68		0	5	28	5	83	62	15	12	198
1964	56	79	0.4	0	55	5	36	20	62	54	54	232
1965	963	77	9.3	6	7	59	9	56	43	74	9	254
1966	1320	78	0.0	0	19	5	28	8	54	19	5	133
1967	131	85	0.0	0	3	35	9	15	26	19	16	107
1968	12	86		0	0	6	18	6	20	22	7	72
1969	81	80	0.0	0	0	5	10	21	6	23	3	65
1970	178	81	0.0	0	4	16	20	46	37	56	25	179
1971	91	78	0.0	1	0	3	7	2	9	23	**69**	45
1972	30	84	0.5	0	11	3	0	0	2	8	**9**	24
1973	2155	85	0.0	0	6	14	1	1	0	6	551	28
1974	355	72	3.0								15	
1975	207	87	0.0	0	240	5	143	14	2	11	3	415
1976	314	64	0.0	0	4	311	5	101	39	41	8	501
1977	957	77	0.0	0	1	11	128	4	52	11	517	207
1978	37	85	12.0	23	0	2	3	53	1	18	12	100
1979	1740	78		1	224	8	17	1	228	30	6	509
1980	6428	79		0	8	293	0	1	3	48	59	353
1981	278	75	2.0	0	1	4	775	28	22	132	10	962
1982	4820	75		0	21	5	10	411	8	31	29	486
1983	6588	80	0.0	0	0	38	5	6	343	28	249	420
1984	364	72	0.0	0	6	10	141	10	13	244	297	424
1985	102	70	0.5	1	31	23	12	212	15	372	38	666
1986	17	72	0.5	4	142	218	29	26	195	309	15	923
1987	5223	62	0.0	1	27	155	31	11	11	69	17	305
1988	4	81	0.0	0	1	11	7	0	3	8	3	30
1989	886	78	0.0	3	4	14	34	4	0	8	8	67
1990	74	72	0.0	2	0	13	19	56	18	17	2	125
1991	86	90	0.0	6	4	3	1	4	19	19	6	56
1992	48	70	0.0	0	0	4	1	10	4	59	0	78
1993	797	79	0.0	0	3	2	2	1	18	40	15	66
1994	66	80	0.0	1	0	3	3	0	2	31	19	40
1995	613	97	0.5	2	4	0	6	2	4	18	243	36
1996	54	87	14.7	2	2	11	3	8	0	14	13	40
1997	956	76	0.0	0	155	17	8	1	5	14	415	200
1998	126	85	0.0	87	0	88	4	10	2	6	202	197
1999	8	97	0.7	40	315	13	122	9	0	4	132	502
2000	590	78	0.7	2	50	100	4	47	2	3	211	208
2001	59	84	2.3	6	56	152	211	14	55	0	283	494
2002	1145	82	8.3	32	122	76	65	120	7	26	72	448
2003	59	84	5.3	0	106	89	46	52	36	17	5	346
2004	1413	79	2.0	0	33	177	61	38	27	40	590	376
2005	81	98	1.3	44	1	39	227	40	53	17	210	421
2006	138	76	1.7	16	261	4	32	214	50	10	*115*	587
2007	1392	81	0.0	12	111	329	20	34	198	67	39	771
2008	335	75	0.0	5	16	99	126	11	42	74		373
2009	194	73	1	32	39	99	138	277	38	150		752

Table A8. Abundance and biomass of pelagic fish (emerald shiners (ES), gizzard shad, and *Alosa* spp. (blueback herring and alewife)) in Oneida Lake since 1994.

	Abundance (fish/ha)					Biomass (kg/ha)				
Year	ES age-0	ES Age1+	Gizzard shad	*Alosa* spp.	Sum	ES age-0	ES Age1+	Gizzard shad	*Alosa* spp.	Sum
1994	3,589	1,352	2,515	607	7,457	2.2	4.1	15.6	6.1	28.0
1995	350	792	538	575	2,255	0.6	3.2	17.2	9.3	30.3
1996	2,909	280	22	492	3,704	2.3	1.0	1.3	5.3	10.0
1997	16,936	1,760	101	14	18,811	15.0	6.4	0.6	0.2	22.3
1998	2,254	5,668	41	3	7,966	1.0	16.1	0.4	0	17.5
1999	7,539	4,093	726	0	12,358	6.1	10.0	8.7	0	24.8
2000	3,463	1,836	1,936	0	7,235	3.4	5.2	6.3	0	14.9
2001	16,112	2,441	2,458	0	21,010	15.2	9.0	23.5	0	47.8
2002	20,529	2,516	2,924	0	25,969	9.4	7.2	5.6	0	22.2
2003	2,645	8,149	2,474	0	13,268	1.7	23.3	13.8	0	38.7
2004	9,057	1,407	2,664	0	13,128	10.1	4.9	14.6	0	29.6
2005	2,597	1,307	2,215	0	6,119	2.6	4.9	47.8	0	55.3
2006	2,651	666	1,716	0	5,033	2.6	2.3	15.5	0	20.4
2007	417	215	1,431	0	2,065	0.6	0.3	14.3	0	15.2
2008	7,900	381	2,073	0	10,354	6.6	1.3	14.6	0	22.5
2009	1,001	1,521	5,969	5	8,496	0.7	4.4	18.8	0.5	24.0

Table A9. Catch/hour of lake sturgeon in large mesh gill nets at 12 standard sites.

Year	Month						
	May	June	July	August	September	October	November
2002	-	0.39	0.35	0.10	0.10	0.16	-
2003	0.32	0.17	0.09	0.09	0.56	-	-
2004	0.35	0.39	0.08	0.37	0.15	-	-
2005	0.18	0.11	-	-	-	-	-
2006	0.31	0.11	-	-	-	-	0.06
2007	0.30	0.11	-	-	-	0.07	-
2008	0.17	0.13	-	-	-	-	-
2009	0.20	0.14	-	-	-	-	-

Table A10. Catches in ½" mesh fyke nets, Oneida Lake 2007-2009 (n=24 sites).

		Mean Catch/Net (±1SE)		
Scientific Name	Common Name	2007	2008	2009
Family Lepisosteidae				
Lepisosteus osseus	Longnose gar (Adult)	0.04 (±0.04)	0.00	0.00
Family Amiidae				
Amia calva	Bowfin (Adult)	0.13 (±0.07)	0.25 (±0.17)	0.21 (±0.10)
Family Clupeidae				
Dorosoma cepedianum	Gizzard shad (YOY)	0.08 (±0.06)	0.21 (±0.10)	0.04 (±0.04)
	Gizzard shad (Adult)	0.08 (±0.06)	0.17 (±0.10)	0.29 (±0.19)
Family Cyprinidae				
Cyprinus carpio	Common carp (Adult)	0.00	0.04 (±0.04)	0.17 (±0.10)
Notemigonus crysoleucas	Golden shiner (All)	0.17 (±0.13)	0.46 (±0.42)	0.25 (±0.17)
Notropis atherinoides	Emerald shiner (All)	0.00	0.04 (±0.04)	0.00
Notropis hudsonius	Spottail shiner (All)	0.13 (±0.07)	0.00	0.17 (±0.17)
Pimephales notatus	Bluntnose minnow (All)	0.00	0.00	0.00
Family Catostomidae				
Catostomus catostomus	Longnose sucker (Adult)	0.04 (±0.04)	0.00	0.00
Catostomus commersoni	White sucker (YOY)	0.00	0.17 (±0.10)	0.00
	White sucker (Adult)	0.58 (±0.19)	0.67 (±0.17)	0.38 (±0.16)
Erimyzon oblongus	Creek chubsucker (All)	0.04 (±0.04)	0.00	0.08 (±0.08)
Moxostoma valenciennesi	Greater redhorse (Adult)	0.04 (±0.04)	0.04 (±0.04)	0.00

Family Ictaluridae				
Ameiurus natalis	Yellow bullhead (YOY)	0.00	0.08 (±0.08)	0.00
	Yellow bullhead (Adult)	0.17(±0.10)	0.46 (±0.18)	0.46 (±0.89)
Ameiurus nubulosus	Brown bullhead (YOY)	0.04 (±0.04)	0.00	0.00
	Brown bullhead (Adult)	0.79 (±0.32)	0.88 (±0.35)	0.83 (±0.29)
Family Esocidae				
Esox niger	Chain pickerel (YOY)	0.29 (±0.15)	0.08 (±0.06)	0.00
	Chain pickerel (Adult)	0.08 (±0.06)	0.00	0.04 (±0.04)
Family Gadidae				
Lota lota	Burbot (Adult)	0.04 (±0.04)	0.04 (±0.04)	0.13 (±0.09)
Family Cyprinodontidae				
Fundulus diaphanus	Banded killifish (All)	0.04 (±0.04)	0.00	0.00
Family Percichthyidae				
Morone americana	White perch (YOY)	1.58 (±0.72)	0.04 (±0.04)	5.42 (±4.41)
	White perch (Adult)	0.04 (±0.04)	0.08 (±0.06)	0.00
Family Centrarchidae				
Ambloplites rupestris	Rock bass (YOY)	0.50 (±0.19)	1.00 (±0.30)	0.00
	Rock bass (Adult)	2.58 (±0.56)	1.91 (±0.36)	2.46 (±0.66)
Lepomis cyanellus	Green sunfish (Adult)	0.21 (±0.10)	0.13 (±0.09)	0.21 (±0.17)
Lepomis gibbosus	Pumpkinseed (Adult)	9.54 (±2.34)	12.75 (±4.40)	16.83 (±4.98)
Lepomis macrochirus	Bluegill (Adult)	2.58 (±1.02)	3.58 (±1.23)	9.30 (±6.41)
Lepomis spp.	(YOY - <75mm)	3.29 (±1.39)	3.38 (±1.09)	2.08 (±1.06)
Micropterus dolomieu	Smallmouth bass (YOY)	11.58 (±2.83)	4.75 (±1.13)	2.38 (±0.82)
	Smallmouth bass (Adult)	0.00	0.08 (±0.06)	0.00
Micropterus salmoides	Largemouth bass (YOY)	1.25 (±0.42)	1.96 (±0.53)	0.71 (±0.27)
Micropterus salmoides	Largemouth bass (Adult)	0.08 (±0.08)	0.38 (±0.38)	0.13 (±0.07)
Pomoxis nigromaculatus	Black crappie (YOY)	0.08 (±0.06)	1.95 (±0.53)	0.00
	Black crappie (Adult)	2.29 (±1.00)	1.08 (±0.41)	0.88 (±0.39)

Family Percidae				
Perca flavescens	Yellow perch (YOY)	18.21 (±4.68)	1.50 (±0.56)	0.46 (±0.26)
	Yellow perch (Adult)	16.04 (±3.33)	26.08 (±6.57)	24.46 (±5.60)
Percina caprodes	Logperch (All)	0.08 (±0.08)	0.08 (±0.06)	0.00
Etheostoma olmstedi	Tesselated darter (All)	0.00	0.00	0.00
Sander vitreus	Walleye (YOY)	0.17 (±0.08)	0.38 (±0.21)	0.13 (±0.09)
	Walleye (Adult)	0.54 (±0.12)	0.50 (±0.17)	0.63 (±0.33)
Family Sciaenidae				
Aplodinotus grunniens	Freshwater drum (Adult)	0.04 (±0.04)	0.00	0.13 (±0.09)
Mean Total Catch/Net		**70.58 (±8.99)**	**61.54 (±9.48)**	**66.63 (±14.61)**
Mean # Species/Net		**8.08 (±0.53)**	**7.54 (±0.55)**	**6.50 (±0.40)**

Table A11. Catches in 1/4" mesh fyke nets, Oneida Lake 2008-2009 (2008: n=12 sites; 2009: n=24 sites).

		Mean Catch/Net (±1SE)	
Scientific Name	Common Name	2008	2009
Family Lepisosteidae			
Lepisosteus osseus	Longnose gar (Adult)	0.00	0.00
Family Amiidae			
Amia calva	Bowfin (Adult)	0.14 (±0.14)	0.25 (±0.21)
Family Clupeidae			
Dorosoma cepedianum	Gizzard shad (YOY)	0.07 (±0.07)	0.33 (±0.29)
	Gizzard shad (Adult)	0.00	0.04 (±0.04)
Family Cyprinidae			
Cyprinus carpio	Common carp (Adult)	0.00	0.04 (±0.04)
Notemigonus crysoleucas	Golden shiner (All)	0.07 (±0.07)	0.04 (±0.04)
Notropis atherinoides	Emerald shiner (All)	0.07 (±0.07)	0.04 (±0.04)
Notropis hudsonius	Spottail shiner (All)	0.00	0.75 (±0.44)
Pimephales notatus	Bluntnose minnow (All)	0.21 (±0.21)	7.13 (±5.82)
Family Catostomidae			
Catostomus catostomus	Longnose sucker (Adult)	0.00	0.00
Catostomus commersoni	White sucker (YOY)	0.00	0.00
	White sucker (Adult)	0.00	0.13 (±0.07)
Erimyzon oblongus	Creek chubsucker (All)	0.00	0.04 (±0.04)
Moxostoma valenciennesi	Greater redhorse (Adult)	0.00	0.00
Family Ictaluridae			
Ameiurus natalis	Yellow bullhead (YOY)	0.07 (±0.07)	0.00
	Yellow bullhead (Adult)	0.50 (±0.23)	0.25 (±0.09)
Ameiurus nubulosus	Brown bullhead (YOY)	0.00	0.00
	Brown bullhead (Adult)	0.50 (±0.37)	0.17 (±0.10)
Family Esocidae			
Esox niger	Chain pickerel (YOY)	0.00	0.00
	Chain pickerel (Adult)	0.00	0.04 (±0.04)
Family Gadidae			
Lota lota	Burbot (Adult)	0.21 (±0.15)	0.00

Family Cyprinodontidae			
Fundulus diaphanus	Banded killifish (All)	0.36 (±0.17)	1.21 (±0.61)
Family Percichthyidae			
Morone americana	White perch (YOY)	0.00	0.08 (±0.08)
	White perch (Adult)	0.00	0.00
Family Centrarchidae			
Ambloplites rupestris	Rock bass (YOY)	1.57 (±0.57)	0.92 (±0.38)
	Rock bass (Adult)	2.00 (±0.48)	1.71 (±0.35)
Lepomis cyanellus	Green sunfish (Adult)	0.29 (±0.19)	0.29 (±0.22)
Lepomis gibbosus	Pumpkinseed (Adult)	2.00 (±1.12)	1.67 (±0.50)
Lepomis macrochirus	Bluegill (Adult)	2.43 (±0.92)	4.50 (±2.74)
Lepomis spp.	(YOY - <75mm)	43.29 (±17.33)	237.46 (±66.16)
Micropterus dolomieu	Smallmouth bass (YOY)	12.00 (±5.34)	2.33 (±0.95)
	Smallmouth bass (Adult)	0.07 (±0.07)	0.00
Micropterus salmoides	Largemouth bass (YOY)	2.57 (±0.89)	0.42 (±0.19)
Micropterus salmoides	Largemouth bass (Adult)	0.07 (±0.07)	0.00
Pomoxis nigromaculatus	Black crappie (YOY)	0.07 (±0.07)	0.00
	Black crappie (Adult)	0.21 (±0.15)	0.13 (±0.09)
Family Percidae			
Perca flavescens	Yellow perch (YOY)	18.14 (±5.95)	22.42 (±5.71)
	Yellow perch (Adult)	2.00 (±0.98)	9.42 (±4.10)
Percina caprodes	Logperch (All)	0.07 (±0.07)	0.41 (±0.19)
Etheostoma olmstedi	Tesselated darter (All)	0.07 (±0.07)	0.67 (±0.43)
Sander vitreus	Walleye (YOY)	0.00	0.00
	Walleye (Adult)	0.00	0.00
Family Sciaenidae			
Aplodinotus grunniens	Freshwater drum (Adult)	0.00	0.00
Mean Total Catch/Net		**86.64 (±23.49)**	**284.04 (±67.19)**
Mean # Species/Net		**6.21 (±0.49)**	**6.29 (±0.49)**